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MEMOIRS

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NOTE.

The Authors of the several Papers contained in this Volume, are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

MEMOIRS

OF THE

Literary and Philosophical Society of Manchester.

I.—*On the Separate Pressures of the Aqueous and the Gaseous portions of the Atmosphere.*

By Mr. Alderman Hopkins.

[*Read October 19th and November 2nd*, 1852.]

Meteorologists generally consider that it is desirable to separate the whole of the pressure of the atmosphere on the surface of the earth, into the two pressures of which it is made up; that is, the pressure of the gases, and of the aqueous vapour that is diffused through them. To accomplish this object, the dew-point or point of condensation of the vapour is found, each dew-point having a certain amount of tension or expansive force, which causes the vapour when it is at that point to press on the surface of the earth or against a column of mercury, with the precise amount of force due to that tension. And this pressure of the vapour being subtracted from the total amount of atmospheric pressure as ascertained by the barometer, leaves, it is said, that which belongs to the gases alone.

But the dew-point of vapour is found to be different at different times, as well as in different places; and the amount of vapour pressure will consequently vary accordingly. Near

the equator the dew-point is sometimes at 80° of temperature when the force of the vapour is considered equal to the weight of a column of mercury an inch high, and this vapour is capable of sustaining such a column by pressing against it; whilst in colder latitudes, where the dew-point is say only 32°, the tension of the vapour is capable of sustaining only one-fifth of an inch of mercury. The total atmospheric pressure being supposed always equal to 30 inches of mercury, it follows that the vapour and the gaseous pressures will be differently proportioned in the two supposed cases: in the former the vapour pressure will be $\frac{1}{30}$th of the whole, whilst in the latter it will be only a 150th part of it. The total atmospheric pressure however is not always equal to 30 inches of mercury, as that pressure varies to the extent of about 3 inches, or say from 28 to 31 inches. And on every change of the total atmospheric pressure, it may be necessary to ascertain whether this change is due to an alteration in the vapour or in the gaseous pressure. In the greater fluctuations that take place, the alterations amount to much more than the whole of the vapour pressure, and therefore they must, to a large extent, be attributed to an alteration of the gases; but in other instances the changes are small, and we have to determine whether they are due to an alteration in the pressure of the gases or of the vapour.

There is no reason to believe that the total quantities of the two gases which constitute the greater portion of the atmosphere are ever altered to an appreciable extent, and the quantity of carbonic acid gas that is in it is so small, as to render notice of it unnecessary, but the quantities of vapour found near the surface of the globe vary considerably in different localities.

From the tension of vapour at the surface, whatever it may be, the total quantity of it in the incumbent atmosphere at the time has, by modern meteorologists, been inferred; this inference, however, I have in a former paper shewn to be erroneous. Were vapour existing alone in the atmospheric

space, every portion of it in that space up to a great height would be found to have an incumbent weight resting upon it proportioned to the dew-point in the part: as, were it not for the pressure of such a column, the vapour would in virtue of its elasticity expand upwards and diffuse itself through the space above, until the quantity and tension became duly proportioned to the incumbent pressure and to the temperature of the part. But when the atmospheric space is filled with gases, the vapour that is produced by the evaporation of water, in its ascent to the higher regions, encounters the gases, and is by them obstructed and impeded in its expansion into those regions. The elastic force of the vapour, however, in due time enables some of it to force its way through the gases, and if the whole of the vapour while intermixed with the gases could even slowly diffuse itself through them to as great an extent as it would in free space, and finally attain a state of rest, the upper portion of the vapour would, as if it were free, press on the lower, which by its tension would determine the dew-point in the part. This degree of expansion and diffusion, however, it cannot accomplish, because whilst the vapour is impeded in its rising, the cold of the gases in the upper regions of the atmosphere is regularly condensing a part of the vapour as it rises, and this cold effectually prevents the atmospheric space from being filled with vapour to the extent that it would be if no gases were there to cool it. The degree of tension of vapour at the surface is therefore due, not solely to the incumbent pressure of the upper vapour, but only in part to that cause, and partly to the impediment which the gases present to its expansion, until additional evaporation accumulates vapour sufficient to overcome successively, to a certain extent, the obstruction of the gases, and to produce the dew-point and tension that are actually found.

In this way evaporation of water from the surface of the sea, near the equator, produces the vapour that has a dew-point of 80°, and the total weight of the atmosphere there

being supposed equal to 30 inches of mercury, the vapour has been presumed to be equal in weight to an inch of mercury. The *tension* of the vapour being found equal to the inch of mercury, it has been assumed that its *weight* was also equal. Tension and weight of vapour are not however identical, and the tension in this case is due to partial confinement under a particular temperature, and confined vapour we know may have its tension increased by heat to a great extent without any increase of its weight. It should be remembered too, that it is not near to the surface of the earth alone that the gases obstruct the expansion of the vapour, but in their whole mass, through which the vapour is regularly trying to force its way by the exertion of its power of expansion. The vapour passing from the surface upwards has to force its way successively through the whole mass of the obstructing medium, and each portion of the vapour below becomes, to that which is expanding above it, a base, or fulcrum, from which the elastic force is exerted,—so that the whole resistance of the gases through which the rising vapour is penetrating is transmitted downward through the lower vapour, and that aggregate resistance contributes to the formation of the degree of vapour tension that is found near the surface. The tension of vapour shewing a dew-point of 80°, does not therefore indicate that vapour equal in weight to an inch of mercury exists in the atmospheric column. The quantity of vapour, for the reasons just given, must be considered much less, and it may for the present be supposed to be equal to only half an inch of mercury.

But it does not follow that, when there is tropical vapour equal in weight to only half an inch of mercury, there must be a weight of 29½ inches of the gases, in order to make up the total 30 inches, the assumed weight of the atmosphere. For the cold of the gases may be, and is, regularly condensing some of the vapour as it ascends, and converting it into small globules of water, which remain in the atmosphere as water and not as vapour. This is commonly seen in the mist

that hangs over the tropical seas, which mist is made up of minute particles of water that have been produced by cold from the ascending vapour, and this mist is floating in the mass of the gases. These particles of water, however, though each may be small, are assuredly not destitute of weight, and whatever weight they may have must be added to that of the body in which they are floating, just as the weight of wood, or any other light substance that may be put into water contained within a vessel, will be added to the weight of the water that is in it, and will increase the total pressure on the bottom of the vessel. And the weight of the particles of water that are thus floating in the atmosphere, though sustained immediately by the gases, is added to their weight, and the weight of the liquid particles finally increases the density of the gases near the surface, and augments their pressure upon it. The total atmospheric pressure then,—that which is measured by the barometer, is, under such circumstances as have been described, made up of *three*, and not of *two* parts: first, that of the aëriform substance, aqueous vapour,—secondly, that of the atmospheric gases,—and thirdly, that of the particles of water that are floating in, and are principally sustained by, the gases; and of these three portions the first and the last are frequently undergoing changes which considerably vary their quantities, and consequently their weight and pressure on the surface of the earth and on the barometer.

Over the sea, near the equator, where the dew-point is at 80°, the temperature during the night will be generally about the same as the dew-point, and therefore little or no evaporation will take place at night. But the rising sun increases the temperature, when evaporation begins, and additional vapour is generally thrown into the atmosphere, increasing its total weight and pressure. But as this vapour expands successively into the upper regions, some of it is condensed by the cold of the gases through which it has to pass, and

is converted into particles of water which for some time float in the air. Now these particles, being sustained by the gases, their weight is transmitted downwards through the gases, and it must increase the total gaseous pressure on the surface. As the sun rises in the heavens, temperature and evaporation increase, and more aqueous matter passes into the atmosphere, to remain for a time vapour, and then to become water in the upper regions; and, the process continuing whilst the temperature is increasing, the total weight of the aqueous matter, in both the aëriform and the liquid state, is increased.

That this process really takes place, particularly in warm latitudes, is sufficiently evident from the daily evaporation that is known to be taking place from all wet surfaces. With the daily rise of temperature a certain weight of exposed water disappears in a given time, and it is known to pass into the atmospheric space above, where it can be followed and detected: and it must accumulate there in some way until it is formed into rain or snow. But until such rain or snow *fall*, the aqueous matter, having a certain weight, must remain in the atmosphere in one or both of the two forms described, and that weight must constitute a part of the general atmospheric pressure.

In latitudes distant from the equator, the temperature over the sea is generally lower in proportion to that distance, and the daily increase of evaporation is there less palpable than near the equator, but results similar in their nature will always be found, as fresh vapour to some extent is every day sent into the atmosphere in all latitudes, and some of it is ordinarily condensed in upper regions, and becomes either incipient or palpable cloud floating in and resting upon the air, thus increasing the total atmospheric pressure. And, provided that no other alterations were taking place at the time, careful observation of the barometer might no doubt detect the daily change, and shew it to be the greatest in the hottest and the least in the coldest latitudes. The whole

aqueous pressure would then be found to increase with the rising temperature up to some particular time; after which, as temperature declined dew would form in the lower regions, and the cold of the night would return to the earth or sea the water which had been taken from it by the heat of the day. The total aqueous pressure would then be shewn to have, like daily temperature, one rise and one fall in the twenty-four hours.

But the simplicity of this process is broken in upon and destroyed by another effect that is produced during the day. When vapour, in the day, is condensed by cold in the upper regions of the atmosphere, heat, previously latent, is set free, and this heat attaches itself to and expands the gases that are in the part, and renders them lighter than the adjoining gases at the same elevation which have not been disturbed by the condensation of vapour. The warmed gases being thus rendered lighter are forced upwards by those that are colder and heavier, when through further expansion fresh condensation takes place, a new heating of the gases occurs, and the process is repeated in an ascending column of air and vapour. The vapour thus carried up by the gases then exerts less incumbent pressure on that which remains below, and this favours further evaporation, and thus permits more vapour to pass from the surface into the atmosphere to increase its total weight and pressure. But this increase of vapour near the surface is, at some part of the process, counterbalanced by the lightening of the gases. These, as they expand by heat, remove a part of their mass which previously pressed on the surface within the locality, to an adjoining part, and the *gaseous* pressure in the column is thereby reduced.* We have then two alterations taking place in the atmosphere at the same time, which

* Perouse says—"A few days after our departure from Teneriffe we left those serene skies only found in the temperate zone; instead of which a dull whiteness, between fog and cloud, always prevailed. The horizon was contracted within less than three leagues, but after sunset the vapour was dissipated and the nights were constantly fine."—P. 19.

have opposite tendencies, one, the increase of aqueous matter tending to make the total atmospheric pressure more, and the other, the lightening of the gases by heat, tending to make it less. The former produces the greater effect up to say ten o'clock in the morning, by which time the whole atmosphere has become heavier, and the barometer has been raised;—but after that hour the heating of the gases produces the superior effect, and the barometer falls. Now this fall of the barometer, it is contended, is a consequence of a reduction of gaseous pressure, and that reduction must be sufficiently great, not only to produce the fall of the barometer that occurs, but also to do it while the aqueous matter in the atmosphere is increasing in quantity and weight.

But these opposite changes in the constituents of the atmosphere are not always indicated by the dew-point or tension of vapour near the surface; for it is frequently found that when the aqueous portion of the atmosphere is increasing the most rapidly in quantity and weight, the dew-point is falling, and there is consequently a reduction in the vapour pressure on the surface.

This curious fact may perhaps be observed the most readily on the sands of a sea shore, which, having been recently covered by a tide, are exposed to the action of the morning sun. That luminary, by raising the temperature of the moist sand, evaporates water from it with superior energy,—fills the lowest stratum of the air with new vapour, which, on account of the obstruction presented by the gases, expands with difficulty, and therefore shews great tension and a high dew-point near the surface. Indeed at such times the dew-point is often about the same as the temperature, the air being almost saturated with vapour; and incipient cloud is forming at various elevations. But, under these circumstances, let a thick cumulous cloud form above, as it very often does, and then some of the vapour that had saturated the lower air is carried up with the warmed gases which ascend within the cloud,—when

the pressure of the upper vapour on the lower is reduced,—the lower vapour consequently expands more freely, its tension becomes less, and the dew-point sinks. In short, we have in this case all the common indications from tension of a reduction, and not an increase, having taken place in the quantity of vapour existing in the atmospheric column. It has, however, been shewn that these indications are all effects of a process (cloud formation) which is really taking additional quantities of aqueous matter into the higher parts of the atmosphere; whilst the same process, by relieving the water which is in the moist sand below of part of the vapour pressure which had previously existed on it, allows fresh vapour to rise from the sand and to pass more freely into the air. Thus as the cumulous cloud is forming, and in proportion to the rapidity of its formation, the tension of vapour diminishes near the surface almost up to the time when rain begins to fall from the cloud; shewing that a reduction of the tension of vapour may be accompanied by an absolute increase in the weight of the aqueous portion of the atmosphere, and proving that the tension near the surface is not a true indicator of the quantity of aqueous matter in the incumbent column.

What has been just stated is closely connected with the diurnal sea breezes that are found on many coasts, and with the daily rise and fall of the barometer. The sun when advancing towards the zenith heats the surface of the land in those parts more than that of the adjoining sea, and produces more energetic evaporation from any water that may be on the land than that which takes place from the cooler sea. The vapour produced from the land therefore penetrates the higher regions of the air sooner than that which rises from the sea, and some of the former is condensed sooner than the latter, without forming palpable cloud. At the commencement of this condensation some portion of heat is liberated, and the air over the land is thereby warmed and expanded,

when it rises, leaving the cooler air from the sea to flow in and supply its place near the surface. In due time, as condensation proceeds, palpable cloud may be formed over the land, and more heat be there liberated, when the ascending current of air will rise more rapidly, and the sea air blow in stronger to supply its place; and, the whole operations being carried on with increased energy, thick cloud may be formed, and additional quantities of aqueous matter be borne into the higher regions.

In the earlier part of this process, and before palpable cloud is formed, the fresh vapour that passes into the air shews itself by its pressure raising the barometer; and this pressure must be sufficient, not only to do that, but also to counteract the influence of the slight heating of the air consequent on the formation of incipient cloud. That such heating really takes place may be inferred from the dimming of the atmosphere by the mist that at the time pervades it; but this early heating cannot lighten the gases so much as the increase of vapour makes the aqueous portion heavier, because the barometer rises. It is, however, after a certain time, with a diminishing rapidity that it rises, until the two forces become equal, when the rise of the barometer ceases. But this cessation cannot result from any stoppage of the supply of vapour that had previously raised the barometer, as the increasing evaporation which is going on at the surface shews that that supply is more abundant than it was before. The cessation of the rise must therefore be caused by the countervailing influence of the increased quantity of heat that is liberated by the condensation of vapour.

But soon afterwards, the barometer begins to fall, and this it does although the quantity and consequently the weight of the vapour sent into the atmosphere by evaporation is still increasing, and the whole of it, or of the cloud into which it is converted, is there accumulated. This fall of the barometer

therefore cannot be attributed to any diminution in the quantity of the aqueous constituent of the atmosphere, but is clearly traceable to the warming and lightening effect of condensation of vapour on the gases. A local stratum of the atmosphere of some certain depth or thickness is evidently thereby rendered lighter, when it presses with reduced weight on the mercury of the barometer. And this reduction in the weight of the gases must be really greater than is indicated by the fall of the barometer, to the extent of the known increase in the weight of the aqueous element of pressure. The increase of that element would have made the barometer rise, had there been no heating, and it must consequently counteract the fall which is taking place from the heating to a corresponding extent.

We have then a barometer falling from say ten o'clock in the morning, when we know that additional quantities of aqueous matter are directly or indirectly pressing upon it; and as these additional quantities remain in the air until say about four o'clock in the afternoon, during which time the barometer continues to fall, that fall can be attributed only to the lightening effect of condensation. This condensation is at the same time seen to take place in the formation of cloud, whilst the generally moderate increase of the tension of vapour below, or its stationary condition, or its occasional positive decrease, shews that that vapour is expanding into and penetrating the air with proportionate facility, and is freely ascending to form cloud. During this period, therefore, that is to say, from ten in the morning to four in the afternoon, the tension of vapour near the surface is not a true indicator of the total quantity of aqueous matter that is in the atmospheric space; and the whole evidence presented obliges us to conclude that much of that matter then exists in the form of minute globules of water, which float in and rest upon the gases, leaving them to sustain the weight of the globules, which weight must increase the pressure of the gases on the

surface, notwithstanding that their proper pressure has been made positively less by the warming and lightening influence of condensation.

The local and particular causes of these small changes may be best traced, when they occur with such constancy and regularity as will enable us with tolerable certainty to connect each change with the cause that produces it. The daily fluctuations of the barometer, and the occurrence of daily sea breezes in certain parts, afford therefore the best means of studying the subject, but there seems no reason to doubt that the same causes, whatever they may be, which are in operation in those parts, although modified by circumstances, produce the more extensive and irregular alterations which are found to take place in many parts of the world.

The general gaseous atmosphere, when at rest, has an equilibrium of pressure at the surface of the sea: it would therefore be the same in all parts of the world, if the temperature were everywhere the same at the same level. And those changes of temperature, in the mass of the atmosphere, which are produced directly by solar rays, are so gradual and slow as to enable such a highly elastic body as the atmosphere readily to re-establish the equilibrium after it had been disturbed by direct solar heat. The gaseous pressure, therefore, would be about the same over every part of the globe at the level of the sea, were there not some other disturbing cause that operates locally; and that there is such a cause, is sufficiently indicated by the local and temporary changes of the barometer that take place in various parts. Attempts have been made, not entirely without success, to trace iso-barometric lines over the globe, and if we had them in considerable numbers that could be relied upon, they might materially assist in our inquiries.

With reference to this subject Kaemtz says—"We may admit that—

	mm.
At the sea-coast the general mean pressure is	761·35 *
At the equator it is only about.....	758
At the latitude of 10° the pressure increases, and between 30° and 40° of latitude it attains its maximum.....	762 or 764=763
Starting from this zone, it diminishes to.....	760
And more north, it descends to about.....	756."

This imperfect statement of atmospheric pressure in different latitudes is made up of averages, it presents a range of nearly a quarter of an inch of mercury; and Kaemtz appears to think that the amount of pressure has some dependence on mere latitude. In speaking, in the same part of his book, of the total pressure as ascertained by the barometer, he does not, however, deem it necessary to distinguish the aqueous portion from the gaseous.

But there are parts of the world where the average difference of pressure is more considerable than any of those just given. In Schouw's table Tripoli is put down as having a mean of 767·41$^{mm.}$, whilst Reikiavig, in Iceland, has one of only 752$^{mm.}$, which makes a difference between these two places of more than half an inch of mercury. This difference is, however, much exceeded by places in the southern hemisphere. Captain Foster found that the average pressure near Cape Horn, for a considerable period, was only about 29·2$^{in.}$, whilst at Valparaiso it is 30·1$^{in.}$, and at the Cape of Good Hope, 30·2$^{in.}$ Captain Ross also found that in the parts of the antarctic seas which he visited, the pressure was very low, even less than about Cape Horn. Now, in these localities, the respective pressures found, though so unequal, are general averages, and we have to endeavour to ascertain what can cause such long continued unequal pressures, in a body

* 762 millimetres are equal to 30 inches of mercury.

like the atmosphere, which tends so strongly to establish an equilibrium.

In doing this, it will be necessary to bear in mind the causes that are presumed to be in operation to produce the results, namely, varying quantities of aqueous matter in the atmosphere, and local alterations of gaseous temperature; and these causes are considered sufficiently powerful to produce *all* the effects exhibited in the different latitudes; taking the parts about the equator first, with a dew-point of 80°, indicating, according to common assumption, a quantity of vapour in the atmospheric column equal to an inch of mercury, which would leave 29 inches of gaseous pressure to make up the total, supposed to be 30 inches. But with the high gaseous pressure which is admitted to exist on each side of this part of the globe, and with such winds blowing from each side towards it as the north and south-eastern trade winds, how can we imagine that gaseous pressure can be so low in this locality as is thus represented,—only 29 inches? Direct solar heating of the mass of the atmosphere, as has been shewn, is never considerable, it being confined mostly to the portion near the surface; and that heating would tend to heap up the gases within the tropics to enable them to flow over north and south towards the polar regions; it is, therefore, difficult even to conceive that the direct influence of the sun could make the gaseous pressure here so small, as it must be if an inch of mercury is to be allowed for vapour pressure.

For reasons already given, however, the real quantity of aqueous matter in the part, in the two forms of vapour and globules of water, cannot be considered to be much less than that named, that is, a quantity equal in weight to an inch of mercury. Because, although there is certainly much less vapour in the upper part of the atmosphere than has been supposed, there is here much water floating in it, as is seen in the thick stratum of mist that constantly fills the air in the

part. But this mist being regularly formed by successive condensations of vapour, and the vapour being as regularly carried up in an ascending current that attains a great height, is constantly heating and expanding the gases. Condensation, therefore, may be confidently presumed to heat, expand, and lighten the gases to so great an extent as to make their pressure, even when added to that of the aqueous matter that is present, less than the mean, and not more than it is actually found at or near to the equator.

The parts over the Atlantic Ocean, distant say about 30° of latitude from the equator on each side, where the barometer stands the highest, are occupied to a considerable extent by the north and south-eastern trade winds, which have but little condensation of vapour going on in them, and the great mass of the air in these winds will consequently not be heated by condensation. We may therefore conclude that the cool state of the gases in these parts renders them heavy, and produces the superior average atmospheric pressure that is found in these latitudes.

As we proceed farther from the equator, the general temperature is lower and the tension of vapour is less; the former tends to increase and the latter to decrease the total pressure; and where the atmosphere is undisturbed by condensation, the two causes would appear to produce nearly a mean atmospheric pressure. This is seen principally in the northern parts of America and Asia, where there is but little vapour, and that little is not much disturbed by condensation. In Iceland, however, where there is much condensation, the pressure, as we have seen, is low. The same general facts are traceable in this country and on the coast of Norway, all those places shewing effects of condensation.

In the southern hemisphere there are features not observable in the northern, resulting apparently from the different proportions of land and water surfaces, in the two parts. In the northern the great extent of land leaves but a comparatively

small extent of water from which evaporation takes place, hence the atmosphere is there comparatively dry and clear, and the dew-point generally low compared with the temperature. But the southern hemisphere, beyond the latitude of say 50°, is almost wholly sea. Evaporation consequently takes place from a large surface of water, and much vapour is sent into the atmosphere, making the dew-point high for the temperature. The air is consequently generally filled with mist, in this respect resembling the hazy tropical regions; and the extensive condensation warms the air in the middle and upper parts of the atmosphere, and makes the whole mass of air swell and expand, leaving it lighter than in the other hemisphere. The solar rays which on the broad extent of land of the northern hemisphere heat *the land* to a high temperature, are in the south united with water, and pass in vapour into the atmosphere. The quantity of aqueous matter in the air in the south must therefore be large, whilst the total atmospheric pressure is found to be small; the gaseous pressure must consequently be small. This state of the southern atmosphere, however, seems consequent on—not the large proportional surface of water alone, but also on the few elevations that exist there to bring on local condensation. Spread over Europe and the western part of North America, extending into the polar regions, there is a large number of mountains up which winds carry vapour, where it is extensively condensed, and these elevated localities become atmospheric vortices, into which more vapour is borne by the winds from great distances, to be there condensed. The northern atmosphere is thus relieved from a considerable part of its vapour, as it always is, by extensive condensation. It is well known, for instance, that a thunder storm clears the air of vapour. In summer, when evaporation is active, the air in a short time is charged nearly up to the point of saturation, when from some cause which we need not trace a thunder storm occurs. The vapour is first carried sufficiently high to commence conden-

sation, and a local ascending current is created, into which adjoining air and vapour rush from considerable distances, and are carried to the higher regions to have the vapour condensed to a large extent by the cold due to the elevation: the result is a heavy fall of rain. The vapour that went up as an aëriform substance comes down as a liquid, leaving the atmosphere dry and clear. In just the same way many mountains condense the vapour of the northern hemisphere, leaving the air there comparatively free from it, and ready to acquire the cool temperature which belongs to dry air in the middle and upper regions of northern latitudes. In the southern hemisphere, particularly beyond 50° of latitude, there are few elevations of land to collect and condense the vapour that is constantly furnished from the immense surface of the southern ocean; it is therefore slowly but extensively condensed in the open atmosphere, and to a certain extent warms and swells it, leaving the whole atmosphere less heavy than in the north.

But though there are only few elevations in the south, as compared with the north, there are some, and they shew the effects of the peculiar state of the atmosphere in this hemisphere. The few elevations that exist there are remarkable for having an abundance of rain, and for the strength and continuance of the winds that blow about them. These striking features are seen in Kerguelen's land,—Van Diemens' land,—New Zealand,—Auckland and Campbell's islands, and generally about such elevated land as exists in the colder latitudes of the hemisphere. But distinguished among them may be particularly noticed the extreme point of South America about Cape Horn. Up the high lands of this part of the world, the saturated air of the southern hemisphere rushes with a force and constancy not to be paralleled in any other part. Deluges of rain are almost continuous, and the vortices created by them cause the saturated air to press towards them from a large portion of the southern ocean, reaching almost to New Zealand on the west, and far to the

south, as is shewn by the general direction of the wind in those parts. This abundance of condensation of vapour must heat the air in the vicinity of Cape Horn up to a considerable elevation, and render a thick stratum of it light, thus accounting for the very low barometer observed there by Captain Foster. The neighbourhood of Victoria land, as ascertained by Captain Ross, presents the same general features as Cape Horn, allowing for the greater proximity of the former to the pole. The general gloom of the sky in this part,—the frequent falls of rain and snow, and the low barometer,—all indicate the presence of an atmosphere highly charged with vapour in proportion to the temperature at the surface, which atmosphere we presume must be drawn from warmer latitudes towards the part by condensation. There being then an abundance of aqueous matter in the air to furnish its full proportion of weight, the low barometric pressure that is found in these localities is evidently caused by the warming and lightening of the gases, but the aqueous matter is not all in the form of vapour. The particles of water that cause the thick and gloomy mist have their proportion of the weight, though it may be sustained by the gases in which they float,—that weight however must be counteracted by the lightening of the gases themselves, to produce the low aggregate pressure that is shewn by the barometer to exist there.

From such evidence as can be obtained on the subject, we thus arrive at the conclusion, that in every part of the world, where there is a high average barometer, it is due to the gases in the part, up to a considerable height, having fully acquired the low temperature due to their elevation,—as then a greater weight of air exists in the same space than when the gases are locally warmed;—whilst where the barometer is low, it is always a consequence of heat having been conveyed by vapour to warm the gases. This view also enables us to account for the puzzling fact so long observed, of a moist atmosphere being accompanied by a low, and a dry one by a

high barometer; which, as the material that constituted that moisture adds to the weight of dry air, seemed very surprising and even contradictory. It also authorises us to correct an error that is to be found in most of our meteorological works, namely, that moist, is lighter than dry air! There can be no doubt, that, considered independently of temperature, any vapour passed into dry air adds to the total weight of the mixture as measured by the barometer. The whole of the gases on the globe have a certain weight, be it more or less, and all the aqueous matter that is diffused through them has also a certain weight; and when we speak of, or compute, the total weight of the atmosphere, we have to add the latter to the former. Temperature being the same, to say that moist air is lighter than dry air, is to say that the whole is less than a part. It is true that the specific gravity of aqueous vapour, considered separately, is less than that of the atmospheric gases, but when mixed with them the vapour adds as much weight to the gases as it possesses. The vapour penetrates into, and exists within the gases, just as much as the gases exist in the vapour, each having its separate weight; and when both are in a state of rest, each presses separately and independently on the surface of the earth, and against the mercury of a barometer which may be placed on that surface.

Some meteorologists, indeed, from their language, seem to think that when vapour first penetrates the gases, they are swelled by it, and thus become permanently lighter, and this idea is countenanced by the temporary effect that is produced when vapour first enters the gases. Vapour, discharged suddenly against a mass of the gases, impinges on them, and when it penetrates them and is pressing further through them, it no doubt tends to force them forward or upward, as the case may be. This is shewn by steam being used to blow out air from a vessel that contains it, but this is no more than what one gas will do with another. Nitrogen will act thus on oxygen, and oxygen on nitrogen; but when these gases have fully

penetrated each other, and each rests on the earth, each exists independently of the other, and is in the state that it would be if it were in the atmospheric space alone; and so it is with the atmospheric vapour and the gases. It may, and we have presumed that it does, at first and temporarily act against the gases. It has, indeed, been shewn that the actual tension of the vapour which is ordinarily found in the middle of the day near the surface of the earth, is partly due to this cause, the gases obstructing temporarily its expansion into the atmospheric space. But when the vapour has fully diffused itself through the gases, and rests independently on the earth, it exists within them without affecting them. This is a consequence of the law, discovered by Dalton, of mechanical diffusion of aëriform substances through each other, and of their independence of each other when so diffused.

Globules of water, on the contrary, when floating in the gases, rest upon them, because those globules are not aëriform, but liquid, and the gases sustain them for the time because they interpose an obstruction to their descent, just as they would to the descent of any other light substance. But the vapour being an aëriform body, presses with a weight of its own on the surface, and although for the reasons given we cannot admit the tension of vapour to be always a correct measure of its own weight, yet there is no doubt that it has a certain amount of pressure, and that amount is so much to be added to the pressure of the gases,—sustaining, as they often do, at the same time, the weight of the particles of water that may be floating in them.

There is, then, no reason to doubt, that the greater changes of total average atmospheric pressure, as measured by the barometer, which take place in different parts of the world, are due to the same causes as have been traced in the smaller ones. But we know that such very great and sudden reductions of pressure sometimes occur, as to cause the

barometer, in a short time, to fall as much as two or even three inches; and through the extreme mobility of the materials that are in action, great difficulty has been experienced in explaining, or even in conceiving, what can be the cause of such great and rapid falls. The difficulty, indeed, is so great as to oblige us to have recourse to analogy, and to apply the knowledge which we have obtained of the nature of the smaller and the average changes, to the larger and sudden ones;—presuming, that when certain causes, operating with a given degree of energy, produce a certain amount of effect, the same causes, when operating with greater energy, will produce a proportionately greater effect. Having seen that lightening the gases, by the warming process of condensation, of vapour existing within the mass of the atmosphere, was the cause of the fall of the barometer when the changes were small and regular, as well as when considerable averages were taken, we may reasonably presume that the same cause is in operation in great, irregular, and sudden changes. Let us, then, endeavour, from a general view of the subject, to conceive what may be the circumstances that lead to one of those great falls of the barometer which sometimes take place.

Say that, in a certain locality the atmosphere to a considerable height is charged with as much vapour as it can hold in an uncondensed form, and that in the outer portion of it, or in adjoining parts, dissolving clouds exist which by their evaporation cool the gases intermixed with them, and cause the gases to descend. The uncooled saturated air being then a little warmer and lighter than the cooled air, the former will be pressed upwards by the latter, and some of the vapour in the ascending column will be condensed. The whole of the column will now be warmed and expanded by the condensation that takes place within itself, and the heavier adjoining air will press and follow it up with greater velocity, the process increasing in energy and rapidity as condensation proceeds, until the whole ascending column, up to a great

height in the atmosphere, is heated and made very light. Under these circumstances the pressure of the warmed column on the surface must be materially reduced, and a barometer placed under the column would, by its fall, shew the extent of the reduction. But notwithstanding this reduction of total pressure, the quantity of aqueous vapour in the column must, under the circumstances described, be increased, the warmed ascending current permitting more of it to remain uncondensed in the higher part than would have been possible at that height with the previous lower temperature: whilst the cloud which is always formed at such times in the outer part of the column would load the gases there with additional globules of water, together making the aqueous part of the atmosphere heavier. The heating and expanding of the gases must, therefore, be sufficiently great to counteract the increased weight of the aqueous matter, and, at the same time, greatly to reduce its own weight. And to some such heating as that just described we have to attribute the great falls of the barometer, approaching three inches of mercury, that sometimes occur; and when such a change takes place in a whole column, it is obvious that the heavy adjoining air will rush as a wind towards the comparative vacuum that exists; but this rush, be it observed, does not occur until after the vacuum has been formed:—the fall of the barometer may therefore precede the rush of wind, or give warning of the coming storm.

This will also account for the fact, that the barometer sometimes begins to rise during the storm. The heating and expanding of the air takes place as soon as the first vapour is condensed, and when only incipient cloud, not sufficiently dense to be seen, is forming. And when the same process is going on all around the observer, to a considerable distance, as is common under such circumstances, it may be some time before sufficient cloud is produced to become palpable to the view; for the cumulus cloud, when forming, like a gas jet in

burning, makes for itself an envelope, but to see this envelope it is necessary to be outside of it, and looking at it in profile. To those beneath, it appears at first to be only a slight mist, which afterwards darkens as condensation increases, until at last a black thunder cloud may be formed. But the condensation of vapour may then possibly have diminished, and the rushing in of cool air may have partially restored the equilibrium of pressure, and the barometer may have begun to rise though the storm may still be raging. We may conclude, then, that rapid expansion of the column of air by heat of condensation, up to a considerable height in the atmosphere, is the cause of the great and sudden falls of the barometer that sometimes occur; and those falls are likely to be the greatest where the heating begins in the lowest, and consequently the densest parts of cold regions, and ascends the highest in those regions. The low heavy air of such parts is greatly expanded by the heat of condensing vapour, and being near the surface, the diminution of pressure that follows, affects only a small area of that surface, within which however the diminution is great. But as we proceed to warmer climates, though the quantity of vapour is there much greater, yet, as condensation commences at a superior elevation, a higher and rarer portion only of the atmospheric gases is expanded by it. Within the tropics, the whole of the lower stratum of the atmosphere is kept warm by condensation of vapour, and extraordinary cases of condensation occur only at considerable elevations,—the diminution of pressure is therefore experienced over a wide extent, but in each particular part of that extent, only in a small degree.

While in the arctic regions, the whole of each particular disturbance is within the view of a single observer, to another, within the tropics, it often appears to have an unlimited range, and seems to fill the whole atmospheric space to a great height. A consequence of this is, that, in any one place within the tropics, the barometer falls but little, seldom more than half an

inch, though the cause of that fall may have been in energetic operation over a very extensive area, producing disturbances of the most formidable character in the upper regions.

It is, however, probable, that very great falls of the barometer take place only when condensation occurs within an atmosphere which is, in the part, below the freezing point, and that the greatest falls occur when the air is the most below freezing. Suppose, for instance, the air at the surface of the earth to be near the freezing point, and to be pretty fully saturated with vapour, when, from some cause, condensation begins near the surface, and an ascending column is formed: the column would, in its ascent, soon pass into air that was below the freezing point, and when it attained the height of 1000 feet, it would have a temperature 10° above the adjoining cold air at the same level, and would be pressed up by it with a force corresponding with the difference of the temperature of the two masses at the same level. But the ascending column is itself cooled by the reduction of incumbent pressure; when, however, it reached 32°, a part of the water that had been produced in the column would be frozen, which would arrest the descent of the temperature and keep it at 32°. The congelation would now liberate fresh heat, to act upon the air and further lighten and raise the column; and this double process of condensation of vapour and congelation of water would continue, and the temperature in the column would remain for some time at 32°, as long as fresh vapour for condensation was supplied from the lower air. The column might thus continue ascending like a rocket, carrying within itself the cause of its ascent, until it reached a height of 2000, or 4000, or 6000 yards, and there would be a difference in the temperature of the ascending column, and of the adjoining air, at equal heights, of 10° at 1000 yards, 20° at 2000 yards, 30° at 3000 yards, and so on, 10° for every additional 1000 yards of elevation.

Now a rise of temperature in the warm column of 20°, would reduce its weight and pressure below that of the adjoining cold air, equal to about two inches of mercury. A difference of 40°, which would be produced at a height of only 4000 yards, would reduce the pressure of the warm column, at the surface, equal to 4 inches of mercury. We see, then, that,—when condensation and congelation take place successively in an ascending column, amply supplied with fresh vapour from below, a force is brought into action capable of reducing the pressure of that column, on the surface of the earth, to a great extent, and that force may be the cause of the greatest descents of the barometer that have been known to occur. It is not here presumed that the supposititious case that has been adduced includes all the circumstances that should be examined, if we were describing a real occurrence, but that case enables us to perceive that there is a power which is sometimes brought into action, that is capable of producing those alterations of atmospheric pressure that have been hitherto considered inexplicable. We see also, that the power is the same in is nature as that which evidently produces other alterations that frequently take place to a smaller extent; and that power results, first, from the warming and lightening of the atmospheric gases by the condensation of vapour that is intermixed with and diffused through them; and, secondly, it may be from the freezing of the particles of water produced by the condensation.

II.—*On the Action of Old Coal-pit Water upon Iron, in the Pendleton Colliery.*

By Mr. E. W. Binney.

[*Read November 16th*, 1852.]

The general use to which iron is now devoted in the erection of buildings, the structure of ships and lighthouses, and in the protection of mines from water, makes every fact in any way connected with its destruction or preservation worthy of being recorded, especially in this Society, where so many valuable communications upon this subject have been read, and so much practical information given to the world.

Cast iron is now used to a great extent for the purpose of "tubbing" water from mine shafts. This process may be briefly described as follows:—In sinking through beds of sand and porous sandstone like those of the lower new red sandstone at Monkwearmouth and other places, or in carrying a shaft through old coal workings down to deeper mines, immense volumes of water are sometimes met with. These are frequently dammed out of the shaft by cylinders of cast iron, put in in segments and firmly wedged, and made water-tight by pieces of wood being driven between them. By these means the water is generally dammed out or pent back, and in the latter case driven into old abandoned workings, which are too often allowed to remain full to save the expense of pumping out. The shaft is thus carried down to great depths without meeting with much difficulty from water.

These dammed-up waters, however, are not only very foul from the mineral matter with which they become charged in the old workings, but they exercise considerable pressure, in

some cases reaching to one or two hundred yards of a column, against the sides of the tubbing. Now, should the iron from any cause give way, great loss of life must necessarily ensue; for that material generally gives but little warning of its breaking, and the irruption of water into the pit before the miners could escape, must therefore prove most disastrous, especially in deep collieries, where there are often but two shafts, and those placed close together.

Mr. Robert Mallet, M.I.C.E., &c., in his valuable reports (published in the 8th and 13th volumes of the Transactions of the British Association for the advancement of Science) upon the action of air and water, whether fresh or salt, clear or foul, and of various temperatures, upon cast iron, wrought iron, and steel, gives many instances of the effects of acid solutions and sea and fresh water upon these metals.

The action of sea water and a mixture of salt and fresh waters upon cast iron, by converting it into what has been called plumbago, is well known, and many instances have been recorded of iron guns and shot having been partially converted into that substance. The guns of the Royal George at Spithead may, amongst many others, be mentioned as a case which has lately come before the public. So certainly is this effect produced, that it strongly behoves those who have charge of the lighthouses now so often erected in the sea upon cast iron pillars, carefully and frequently to inspect such structures, for day by day their supports must be weakened by the action of the salt water.

With regard to the effect of sea water upon wrought iron, there appears to be some difference of opinion, for Mr. Mallet* states that he has in his possession a portion of an ancient anchor taken up in the port of Liverpool, the iron that remained of which was of remarkable purity, and which was converted into plumbago of unusual hardness and brilliancy to the depth of half an inch. This plumbago did not heat on

* Vol. vii. Brit. Ass. Rep., p. 259.

exposure. Its specific gravity is 1·773. This fact militates against an observation made by Mr. Hatchett, and repeated by M. Becquerel, that anchors and other objects of forged iron sustain no alteration in sea water but oxidation; from which we must suppose that the contact of iron and plumbago in the cast iron, produces a current which accelerates the action of the latter.

In Mr. Mallet's report before alluded to, he only mentions one case of the effects produced by waters in mines upon cast iron. This was given by one of the most distinguished members of this Society, the late Dr. William Henry, F.R.S., and is printed in vol. v., p. 66, of the *Annals of Philosophy*. It is entitled—"On the conversion of cast iron pipes into a substance bearing some resemblance to plumbago." As this communication bears so much on the subject of this paper, and appears to be but little known, I shall give it entire. He says—

"I was lately requested by a gentleman who resides in the neighbourhood of Newcastle-upon-Tyne, to examine the nature of the change effected in a cast iron pipe, placed in the shaft of a coal mine near that town. In sinking the shaft it was necessary, as sometimes happens, to put down a *curb*, or cylinder, of cast iron, in order to support a bed of quicksand: and into a suitable opening in this cylinder, the cast iron pipe, three inches diameter, was bolted by means of a *flanche* at its extremity. Its use was to allow an exit to the water and gas which issued from the stratum of quicksand.

"The fragment of the pipe with which I was furnished was of a dark grey colour: its inner surface was smooth and black; and its outer surface had a thin ochrey incrustation. The usual fracture of cast iron was exchanged for an earthy one, except near the centre of the mass, where somewhat of the usual texture of cast iron was still visible. It was soft enough to be easily scraped with a knife, and was readily broken by a slight blow of a hammer. Some parts of it left a black trace on writing paper, but destitute of the lustre which the traces of plumbago exhibit.

"The specific gravity of the specimen was 2·008, and, after being soaked an hour or two in water, it became 2·155.

"Twenty grains of the powdered substance was projected upon 200 grains of melted nitre. The combustion was very feeble, compared with that which happens to plumbago under similar circumstances. After washing off the nitre, there remained 14½ grains, which were almost entirely oxide of iron, consisting probably of 11·2 iron, and 3·3 oxygen.

"A small piece of the pipe, weighing 6½ grains, was passed into a glass tube containing diluted sulphuric acid over mercury. The acid acted very slowly: and, in eight days, when its effect seemed to be complete, only half a cubic inch of hydrogen gas was formed. This was only about $\frac{1}{30}$th of what would have been obtained from the same quantity of cast iron.*

"There remained a black and bulky substance, which, when dried and projected on red hot nitre, burnt rather more vividly than the original substance, but still afforded much oxide of iron.

"It was clear, therefore, that a large share of the metallic part of the pipe had been removed; and that what remained was composed of iron, plumbago, and other impurities usually present in cast iron. With the view of ascertaining the cause of the change, I next examined the water from the bed of quicksand, a bottle of which had been sent along with the fragment of pipe.

"The water had a brackish taste, and was of the specific gravity, 1·008. It gave no traces of iron, either with triple prussiate of potash, or succinate of ammonia. I collected the gas from a wine pint of it, but it was lost by accident before being examined. By the usual methods of analysis, a wine pint gave 64 grains of dry salt, composed of—

Muriate of soda	32
——— magnesia	16
——— lime	10
Sulphate of lime	4
Carbonate of lime	2
	64

* A piece of plumbago from Borrowdale, kept eight days in dilute sulphuric acid, had evolved no gas.

"It is most probably to the agency of the muriates of lime and magnesia, that we are to ascribe the removal of the metallic part of the pipe. I have often remarked the effect of solutions of these salts in discharging writing ink from the labels of bottles to which they have been accidentally applied: and I was lately baffled in several attempts to restore the legibility of some of the MSS. of a most accomplished scholar (the late Mr. Tweddell, of Trin. Coll., Cambridge) which had lain some time under sea water, abounding, as is well known, in muriate of magnesia. The texture of the paper was entire, but the iron basis of the ink, as well as the gallic acid, was entirely removed.

"In that copious repository of valuable knowledge, Dr. Priestley's *Experiments and Observations on Air*, some facts are stated that bear an analogy to the one which I have described. Cast iron nails, he found, dissolved very slowly in diluted sulphuric acid; and left a large proportion of black matter which had the original form of the nails. This experiment, he observes, explains what happens to cast iron pipes in pits, the water of which is impregnated with vitriolic acid; for, in time, they become quite soft, or, as it is called, rotten, and may be cut with a knife.

"In Cornwall, I am informed, cast iron pipes are disused in many of the mines; but this is owing to the presence of sulphate of copper in the water, the corroding effects of which render it necessary to substitute pipes of brass or copper.

"The following fact, which was lately observed at the printing works of a friend of mine, belongs to a different class of phenomena, and is, perhaps, to be accounted for by galvanic agency. In order to confine the heat in some cast iron steam pipes, they were placed in a trough or gutter made of bricks, into which powdered charcoal was tightly rammed. At a place contiguous to a joint, formed by bolting two flanches together, a leak had happened, and when the iron pipe was taken up, it was found, in the neighbourhood of the leaky part, to be perfectly soft and rotten. I was not able to obtain an opportunity of examining the nature of the change by an experiment on the altered iron."

The facts which will be brought before you in this communication occurred in the deep pits of the Pendleton

colliery, near Manchester. This "winning" was commenced by Mr. Fitzgerald on the 17th day of July, 1837, and the Duchess of Lancaster seam of coal was reached in 1840, at a depth of 464 yards from the surface. About 150 yards of cast tubbing, varying from one-half to three-quarters of an inch in thickness, was put into the shafts down to the distance of 150 yards from the surface; behind this was generally a four and a half inch wall of circular bricks, but near the seams of coal a brick wall of one yard in thickness, both grouted at the back with Ardwick lime and gravel. A portion of the tubbing originally made for a shaft of ten feet in diameter was used in these of eight feet. At the time of the accident there was in the old workings of the four feet mine, and the shaft communicating with them, a vertical column of water of about 600 feet, and at the place where the tubbing gave way, three segments of the ten feet castings were used with one of the eight feet; thus forming an imperfect circle.

The colliery continued working until the first day of August, 1843, when the waters from the old four feet mine workings burst through the tubbing in No. 2 shaft, about 140 yards from the surface, and rushed down the remaining 344 yards with fearful violence, displacing the air from the lower part of the workings, and ultimately filling the latter and the shafts up to within 40 feet of the surface. The dip of the strata in the mine was about one in three; so when the workings were filled to the bottom of the shafts, the air and gases in the mine were pent up in the "rise" part, and kept there by the pressure of a column of water of 1,352 feet.

The accident took place in the night, and Mr. Ray had time, from some warning, to withdraw all the men out of the pits, so that there was no loss of life. Many waggons full of coal were near the pit bottom at the time of the irruption of the waters, and they remained there until the mine was drained. Some of the cast iron wheels and wrought iron axles of these

waggons will be mentioned in this communication, and are now exhibited on the table.

On the first day of November, 1844, the pumps for withdrawing the water from the mine were started, and by the second day of February following, the hole where the water had burst into the shaft was reached, and the men commenced to put in the new tubbing. The bottom of the shafts, filled with four yards of dirt, was reached on the 4th day of October, 1846. At the commencement of 1847, the workings were cleared, and the specimens of iron described in this communication brought out of the mine, having been thus buried and immersed about four years and six months.

A description of the specimens will now be given.* These consist of cast and wrought irons. There is no evidence as to their make, either as to the locality where they were made, or whether they are of hot or cold blast manufacture.

First as to the cast iron:—

No. 1 is part of an edge wheel, ten inches in diameter, one inch thick in the centre, formerly belonging to one of the underground waggons. The shape of the wheel is preserved, but the whole substance of the casting has been altered. When first taken out of the pit it was of a brownish black colour, and could be easily cut, like soft clay, with a knife. Since it has been exposed to the air, it has become harder, and is now not so black as it first was. Its fracture is earthy, and not like that of cast iron. The composition of it I am enabled to give through the kindness of my friend, Dr. Robert Angus Smith, F.C.S., who has been at the trouble of analyzing a portion of this specimen. He found it to consist of—

Iron and bases	38·8
Carbon.....	40
Silica	19·7
Its specific gravity is	2·0133

* These specimens, as well as much valuable information, I owe to the kindness of Mr. Andrew Ray, the late intelligent manager of the Pendleton Colliery.

For the sake of comparison, it may be as well to give an analysis of the Dowlais hot-blast iron, No. 4:*—

Suspended graphite	1·22
Combined carbon	2·13
Phosphorus	0·21
Manganese	0·17
Alumina	0·00
Sulphur	0·00
Silica	1·21
Iron	95·06
	100·00

The average specific gravity of cast iron, according to Karsten, is 7·5.†

It will be at once evident that not only has a great alteration taken place in the specific gravity of the specimen, but that a large proportion of its iron has been removed, and its place occupied by carbon and silica, for the bulk and shape of the specimen still remain the same, although it has lost so much of its weight. The iron appears dispersed through the earthy mass in little globules of a bright colour, when viewed under a lens.

Nos. 2, 3, 4, and 5 are specimens of portions of other edge wheels of cast iron. All of them shew a decomposition from the outside to the inside, varying, in different cases, from a third to half an inch, the middle part of the casting still consisting of metallic iron, surrounded by a brownish black substance resembling plumbago. In every respect as to size, and the use to which they were applied, these specimens are the same as No. 1, which, as before described, is altered throughout its whole mass. Whether the iron varied from the last-named specimen, or they were placed in a different position, and thus subjected to other conditions, there is no evidence to shew.

* Mallet's Report, Vol. xiii. Brit. Ass. Rep., p. 4.

† Vol. v., Gmelin's Hand Book of Chemistry, p. 211.

No. 6 is a most interesting specimen of a portion of cast iron tubbing, of an inch in thickness. One side of it appears to have been built into a wall, or somehow covered with a coat of lime, for it is still coated with whitewash, except a portion near the edge, which has a little yellow ochre upon it. Now where the thin covering of lime remains, the iron on that side shews no signs of decomposition, whilst on the other side, where there is no lime, the iron in the centre of the casting has been eaten away to the depth of one-fourth of an inch.

The effect produced upon the wrought irons:—

No. 7 is a chisel of wrought iron, faced with steel, ten inches in length, by three-quarters of an inch in diameter. The iron is corroded and eaten into so as to shew the threads of which it is composed, in some places, to the depth of two-tenths of an inch. This is most marked where the iron and steel join. The steel itself has scarcely been acted upon at all, and the broken point exhibits a fracture just as if it had only been made a few days.

No. 8 is the outside of a 1½ inch axle, which was attached to one of the waggons to which the cast iron wheels previously described belonged. The thickness of it is about one-third of an inch, and it appears as if it had shelled off from the sounder part of the axle. It has not the black plumbago appearance which the cast iron before noticed exhibits, but shews more of the characters of ordinary rust, produced by oxidization of the metal.

No. 9 is a wrought iron hammer, with a handle of ash fixed in it. This specimen appears to have been acted upon more than any of the other specimens of wrought iron, being in some parts, especially the faces, corroded to the depth of one-third of an inch. The threads of iron and every bend in them are beautifully shewn all over the surface of it.

There was another hammer, with steel face, found in the pit. This was corroded in a similar manner to that last

described, but the facings of steel were quite free from injury.

All the wrought iron specimens appear as if they had merely been oxidized, and not converted into plumbago like those of cast iron. This, Hatchett and Becquerel contended, was the case with wrought iron immersed a long time in sea water, and which has been previously alluded to in this paper.

Mr. Ray informs me that neither the wrought nor cast irons heated on first being taken out of the pit and exposed to the air.

Unfortunately no analysis was made of the waters, either at the time of their first breaking into the shaft, or when they were nearly drained out of the mine. These would in all probability be of two descriptions, namely, a small supply of salt water found at the bottom of the mine, containing the chlorides of sodium, magnesium, calcium, and other salts usually found in deep collieries, and the vast body of water which burst into the shaft from the old workings of the four feet mine, extending on the level of the coal four or five miles, where the water had been pent up some years, and, like all such waters, containing an abundance of sulphate of iron and some free sulphuric acid, derived from the decomposition of bisulphide of iron, together with silica and carbonic acid. The pressure of the column of water in the shaft would cause the waters below to be charged with highly condensed air, light carburetted hydrogen, and carbonic acid gases. Waters highly condensed with the latter, both take up considerable amounts of silica, and are known to exercise a destructive action upon iron.

The effect of lime in preserving steel and iron from oxydizing, has been long known and employed by artizans in preserving their tools bright. M. Payen* has presented several memoirs to the Academy of Sciences, on the subject

* Comptes Rendus, Feb. 1837, No. VI.

of local actions on iron, and has added to their explanation the facts he had previously discovered as to the effects of alkaline and saline solutions in retarding or accelerating the corrosive action of water on iron. Sir John Herschel, in a letter in the *Comptes Rendus* for 1836, page 509, recommended an engineer at the Cape of Good Hope to soak some iron pipes with Roman cement, and it produced a good effect in preventing their decomposition.

Mr. Mallet† states that M. Payen's observations as to the power of alkaline waters to protect iron from rust, though seldom applicable, are worthy of further investigation, and an attempt to preserve their rationale; and he then alludes to the circumstance of workmen having been long aware of the fact, and suggests that alkaline solutions might be of considerable use in certain cases, but he makes no mention of coatings of lime on the iron itself.

I have thus given a brief description of the specimens of altered iron, and, so far as I am able, of the circumstances under which such alteration took place. The removal of iron in acid solutions, where the softer portions are first decomposed, is well known, and now generally attributed to the want of homogeneity in its parts, which causes galvanic currents. In waters of the Pendleton colliery, sulphuric, hydro-chloric, and carbonic acids would all be present, and produce their effects upon the iron; but these would, doubtless, be much assisted and increased by the pressure of a vertical column of 1,352 feet of water acting upon the air and gases of the mine. This great pressure on the air and gases (carbonic acid and light carburetted hydrogen) in the mine, would cause the water to be charged with them in a highly condensed state, and thus bring them into a condition peculiarly appropriate for combination.

The cast iron wheels lying in contact with coal, and immersed in water containing acid solutions, would present

† 8th Report of the Brit. Ass., p. 305.

nearly similar conditions to the cast iron pipe with a leak in it, surrounded by charcoal, previously mentioned by Dr. Henry, and a strong galvanic current can be easily supposed to have been generated and the iron removed by this cause; but how the carbon and silica have occupied the place of the iron, I am unable to account for. The waters highly charged with carbonic acid would doubtless take up a large quantity of silica in solution, and as portions of iron were removed, parts of silica might take their places, as it is imagined is the case with fossil woods containing silica. In what manner the carbon was deposited, however, I can give no opinion.

This is a very interesting subject, and requires much further investigation than I can devote to it. The chief object of this communication was to direct the attention of coal masters to the action of old mine waters upon iron, and to recommend them not to place too much trust on metal tubbing alone; and also to point out the protection which lime in the shape of mortar affords to iron under the most severe tests,—for the water that could decompose an inch casting in four and a half years, must be taken as an extreme case. After the facts stated in this paper, no proprietor of a colliery ought to omit placing a bed of hydraulic lime inside the metal tubbing of his shafts, when so simple and cheap a precaution will tend not only to save a great amount of property, but, what is of far greater importance, preserve a number of valuable lives.

Some Ancient and Modern Ideas of Sanitary Economy.

By Robt. Angus Smith, Ph.D., F.C.S.

[*Read November 30th*, 1852.]

As I believe this Society has not yet had introduced to it the subject of Sanitary Economy generally, which certainly is becoming of greater importance daily, I have ventured, although the popular agitation is now somewhat allayed, to bring forward this paper, not as a full discussion of any one point, but rather in the Essay form, putting together some few prominent points, and in a rude way connecting the faint struggles of past and present times in the direction of wise distribution and arrangement, in accordance with acknowledged sanitary laws.

Sanitary economy has scarcely attained for itself a distinctive place in our country or literature; the whole idea is novel to many persons, and it has not the names of great lawgivers, traceable through many generations, from whose dicta it can gain great authority, and from whose judgment it can find many important precedents. We have only lately had a suitable Nuisance Removal Act; we have not in all these centuries been able to remove, legally and thoroughly, what was offensive to the senses or detrimental to the health, even were we sufficiently aware of the consequences. Science has now certainly made us see what before was quite invisible, and the Legislature, recognising the justice of her conclusions, is acting according to her dictates.

And yet, although to us a new era has begun, wherein the community unites to remove evils, and to produce comforts

entirely beyond the power of individuals to attain, there have been no perfectly new truths discovered, no perfectly new principles acted on, and perhaps we may add, no strikingly new laws made. The laws have been better defined, been made more comprehensive and more easily carried out, and known principles have had an extension, both expansively by taking higher ground, and intensively by a care for smaller objects. Yet in examining antiquity, we find it by no means devoid of general laws, nor of clearly defined regulations within certain limits; and we sometimes see indications of great progress in sanitary habits, rising up especially in connection with religious feeling, when the purity of the soul and of the body have been looked on as analogous, and have been conjointly sought after.

We have all some idea of the sanitary laws of at least a portion of the ancients, the Jews, and in them we see no vague ideas about cleanness, but exact and definite rules, the value of which science may take in hand distinctly to prove. But the whole East has more or less of a sanitary code also, as may be seen from the baths of the Mahommedan to the clean clothes and clarified butter of the Hindu. True, with all these the mere form alone remains, having been originally sufficiently important to have been introduced by more than merely legal authority, and bearing amongst them the veneration of a divine command. But this decay is in a great measure owing to the decay of the several nations; the same personal habits cannot be kept up in a falling state. An age of violence or of instability puts down all orderly actions, the result of orderly thoughts; whilst science, or the reasons for acting, sinks, and the arts, each in their order, gradually decline.

On the other hand, a nation in actual warfare does not need the personal habits of a nation at peace. We see, in an unquiet period, that it becomes the glory of a man to live simply and to want little, whilst, in other circumstances,

the same man would seek his highest honour in surrounding himself with all the complex devices and refined ornaments which are the products of civilization and of peace. And although it has been sufficiently shown that a rough, semi-savage life is not productive on the whole of a longer average life, but on the contrary of a shorter, it requires at least no tours to Scotland, Ireland, or Wales for health, and no infirmary life by the sea shore. With them there is no saving of the tender life, no nursing of the weak child into the healthy man, but a rapid death for him who is seized with illness, whilst violence and excitement remove from him many of those smaller evils to which in a calmer life men are liable. The whole community seems to feel the advantage of the change, the farther men remove from the habit of leaving the sick behind, and of killing those who are slow on their march; and in the sympathies which suggest this change, and the circumstances which bring leisure for their growth, we probably find the first rude spot where the natural history of sanitary economy begins.

Looking also at the history of the subject in our own country, and what little I may know of ancient countries or distant ones, it would seem as if the attention to health arose, not so much from any sense of sanitary or of healing measures, as from the simple natural desire of the sick to obtain more comfort of place, whilst the more extended part of the question arose from the desire of appearance and the natural tendency in certain stages of civilization to heap up luxuries; these luxuries being, however, the abuse of instincts evidently tending, to a considerable extent, in a natural and desirable direction. Every virtue is said to have its companion vice; and when a proud king of Nineveh builds a palace for his own vanity, at the expense, no doubt, of much misery, it is not from any keen perception of natural laws that he makes the rooms larger than his predecessors did,—that he puts glass in them, (if indeed that is a glass furnace which is found in

the neighbourhood,) or if he puts in earthenware sewers, and makes it water-tight with pitch from the inexhaustible sources on the banks of the Euphrates. The size is for grandeur, the sewer becomes an absolute necessity in a large house; the mind that constructs the rooms can construct the drains, or perhaps the inferior work may be left to inferior agents, and one most useful invention of these few years was in all probability carried out by some wretched inhabitant of a mud hut in the neighbourhood. Neither when this same king, or even petty savage chief, seeks a drier room or hut and a warmer couch, does he seem to have the least thanks due to him for beginning to teach us that the cold beds on the heath or in the morass are favourable to ague and to fever; on the contrary, these generally seem to have felt themselves in the wrong, being ashamed of their indulgences, and not without a cause: but from the observation of such beginnings that middle course must have arisen which teaches us that neither in the degradation of luxury or of want, can the use of the faculties of men be fully obtained. The effects of indulgence have often led by reaction to the most contrary habits. In a country at various periods given to excessive sloth, was found the home of the most energetic huntsmen; and the description given by Xenophon of the exercises of the Persian youth, shows that attention to personal health was carefully studied, and, in many respects, well understood.

In Egypt, too, where whole strata of extinct habits have been recently dug up, we find remains of sanitary economy among those of pomp and rule,—sometimes beside superstition, or in the happier neighbourhood of taste or of religious feeling. Their physicians were considered admirable, and no doubt that observing nation must have made much progress, with such a complete organization of learned men, appointed to cure each his own department of the body. The organization of that body showed also a something more than a mere regard to personal health; it was an attention

to the health of the community. If, as we may reasonably suppose, there was originally a sanitary intention in embalming their dead, it certainly answered the purpose well, whilst the decayed bodies which now are said to pollute Cairo, were converted into objects of respect and lessons of wisdom to the ancient inhabitants. There is no doubt that their exercises were intended for health as well as amusement, because in a place where daily walks could not be taken as with us, they used all those methods of exercising the muscles by artificial postures, dumb bells, &c., now only becoming common with us. But here, again, the real part of our subject is left unknown; we do not know well how they dealt with crowded communities, with streets, with houses, and the sites of towns.

That sanitary arrangements in towns arose more from the love of appearance and luxury, than from sanitary law, I am more disposed to believe, from the method in which many of these towns have grown. Whether we take Edinburgh or ancient Athens, there has been the same close building of streets, so that the opposite sides nearly met, especially at the top; ceilings being low, and ventilation bad as a consequence. When life in Greece became more languid, these houses became intolerable; the active men of an early period did not feel the discomfort of the small houses they so little used, whilst to the luxurious man of a quieter period, they became intolerable, and gave way to the mansion; whereas it is to be hoped, in modern times, we seek improvement not to prepare idle days for ourselves, but to increase our vigour. Yet in that country, probably, among certain persons, it was as well understood as anywhere, what were the advantages of good air, good water, and good exercise. Hippocrates gives directions to physicians to examine carefully the situation of a town as to winds and as to soil, and is apparently the first writer on sanitary economy in an extended sense. His treatise on *Air, Water, and Situation* is not an uncommon

book, and is to be found in Sir John Sinclair's *Code of Health*. Not having that, I give a rough translation of one sentence—

"When he (the physician) comes to a city, he should consider how it lies, both as to situation, prospect, and winds. For the winds have not all the same strength from the north, south, east, and west. And these things are to be observed,—what water there is about the place; whether soft from marshes, or hard from high rocky places; or hard and saline. The land is also to be looked at, if it is naked and without water, or if it is wooded and moist; whether it is low and suffocating, or high and cold. Also what kind of food the people use, is to be examined; whether they are great drinkers or eaters; or if they delight in exercise or in work, and are temperate in eating and drinking."

He then discusses the effect of climate on men, as to their mental and bodily development, still a contested subject, and it is curious to see that there is no element introduced in the present day which he did not then introduce. True, we have in some cases the element of accuracy affecting certain branches of the subject. If we look at Sir James Clark on *Climate*, however, we see the same things, "hot, dry, cold, moist," and so on, in constant repetition, but the thermometer and rain gauge are made use of in many instances. Still, I imagine, we know as little of the cause as Hippocrates, when he tells us that one wind takes away the appetite, another causes coughing.

Sir J. Clark's book is full of remarks such as these:—

"Florence is subject to sudden transitions of temperature, and to cold piercing winds during the winter and spring." "Rome; the peculiarity of it deserving notice is the stillness of its atmosphere, high winds being comparatively of rare occurrence." Also—"More is to be feared from currents of cold air in winter, than from a confined humid atmosphere, which last is the evil to be avoided during summer."

But even before Hippocrates, evils of this kind were attended to, and Hercules is said to have saved the Elians

from a disease by draining pestiferous ground. The neighbourhood of Rome was healthy or unhealthy according as it was inhabited, nature producing disease, and art health. Cities, also, seem to have been carefully drained before the historic times, whilst a drain tile of modern form has been taken from the neighbourhood of the Euphrates. The Greeks were well aware of the value of having streets wider than they possessed in Athens, although the municipal economists of early times would not permit a change, for fear of the leading men misusing the money,—making what we should call a job; as it seems to have happened there as here, that the best schemes were not always proposed by the most suitable characters.* In the later Empire, however, very particular directions are given as to widening the spaces between houses, removing obstructions from the street, and raising balconies to prevent the street air from being close. Most of these laws came from Rome apparently, and there, also, we find that elegance and security are more looked to than actual health. Houses were not allowed to be above nine stories, not because they occasioned a crowding of the population and a closing of the street, but because they were apt to fall down. In Rome houses were ordered to be five feet apart. Augustus ordered that they should not exceed seventy feet in height, whilst Trajan thought sixty feet high enough. In Constantinople, Zeno ordered all houses to be twelve feet distant from each other, from the ground upwards, that is, they should not project as they rose, nor should they deprive a neighbour of his view of the sea. This looking to the sea was considered very important, as no one was allowed to stop the prospect from houses, excepting from kitchens, baths, stairs, passages, &c.† One too severe law in connection seems to have been useful at times; workmen who did not do their work well, were compelled to make good any damage that might result, or if not able through poverty, they were beaten

* Boeckh's Public Econ. of Athens. † Cod. Just. Lib. viii. Tit. 10.

out of the town; still, I am not aware of any method of teaching them their work, and they were thus kept up to a higher standard of duty than those who paid them. The plan in Manchester, when gas is fitted badly, is to fine the gas-fitter, and if he continues to fit in such a way as to allow the dangerous and unwholesome gas to escape, he is suspended.

In Rome, there were some laws with a merely sanitary object, clearly enough expressed, for example*—"The Prætor took care that all sewers should be cleaned and repaired for the health of the citizens; for uncleaned or unrepaired sewers pollute the atmosphere and are dangerous, if not repaired. This is for private sewers; public sewers have the public care." A sewer is defined—"A hollow place through which any impurity flows." *(Cloaca autem est locus cavus, per quem colluvies quædum fluat).* Also a tube or pipe is said to be comprehended in this definition—"*Cloacæ appellatione et tubus et fistula continetur.*"

It is forbidden, also, to throw refuse on the roads,† either offal or animal refuse, (or to quarrel in the streets is added as a similar nuisance.)

"*Idem ait, Si odore locus pestilentiosus fiat;*"‡ so that smell itself was considered unwholesome or pestilentious.

We have, then, in these early times, the elements to be worked out, a point scarcely worth proving, because the senses of men in all ages might be supposed to teach them to avoid an atmosphere obviously unpleasant, as well as to seek a pleasant or a wholesome one; but the truth is, we had gone back a great deal, and did not believe these things. Ascetic habits—solemn protests against self-indulgence of all kinds—

* "Curavit autem Prætor per haec interdicta ut cloacæ et purgentur et reficiantur: quorum utrumque et ad salubritatem civitatium et ad tutelam pertinet; nam et cœlum pestilens et ruinas minantur immunditiæ cloacarum; (item) si non reficiantur."—(Ulpian, Digesta Just. Lib. xliii. Tit. 23.)

† Lib. xliii. Tit. 9. ‡ Lib. xliii. Tit. 9. (29.)

having spread among the finest minds of both the east and west, produced, no doubt, a carelessness in many respects among the very persons who were most likely to be careful of health; and instead of purifying by washing and by fumigation, as their forefathers, they came to consider numerous sufficiently apparent evils, as not to be remedied by a short-lived race, or as purposely established as trials for our benefit. Another stage of reasoning made men consider them as actual benefits, capable of promoting health, till, when evil consequences could no longer be hidden, it was said, and still is said, through some abuse of a scientific idea, that the greater the number, the greater the benefit, as they then tend to exterminate each other.

Although, therefore, Hippocrates had been praised for fumigating the streets by fires, by the odour of flowers, and by the opening of certain windows and shutting of others, Sir Kenelm Digby, a long time after, when the lesson ought to have been better learnt, tells us that—

"In times of contagion or universal infection of the air, pigeons, cats, dogs, and other hot animals, used to be killed, which make continually a great transpiration or evaporation of spirits which issue forth of evaporation; the pestiferous atoms which are scattered in the air, and accompany it, used to stick to the feathers, skins, or furres."

Yet he did not give up the fires. He says—

"By reason of their (*i.e.* the fires) attraction, they used to make great fires where there is household stuff of men that died of the pestilence, to disinfect them."

But it is curious how directly to the point, at an early time, Ulysses came; when he had killed his suitors, he fumigated the place with sulphur:—

"ως εφαθ· ουδ' απιθηση φιλη τροφος Ευρυκλεια
ηνεγκεν δ' ara πυρ και θηιον· αυταρ Οδυσσευς
ευ διεθειωσεν μεγαρον και δωμα και αυλην."

Hom. Odyss. book 22, l. 492.

Or the whole passage from Cowper's *Homer*—(Pope slurs it over):—

"Bright blast-averting sulphur. Nurse, bring fire
That I may fumigate my walls; then bid
Penelope with her attendants down,
And summon all the women of her train.
But Euryclea thus, his nurse, replied:—
My son, thou hast well said, yet first I will
Serve thee with vest and mantle. Stand not here
In thy own palace, clothed with tatters foul
And beggarly; she will abhor the sight.
Then answer thus, Ulysses wise returned:—
Not so; bring fire for fumigation first:
He said; nor Euryclea his loved nurse
Longer delayed, but sulphur brought and fire,
When he with purifying steams himself
Visited every part, the banquet room,
The vestibule, the court."

I adduce this as a contrast to the opinions of a man of the 17th century, certainly not the most ignorant, for Sir Kenelm Digby was a man of some observation, although of more imagination, and reasons on the "strange subtlety of little bodies which issue forth from living bodies, by means of which our dogs in England will pursue the scent of a man's foot, or of a beast's, many miles." This is in a "Discourse made in a solemn assembly of nobles and learned men, at Montpellier in France;" and shows the strange rational and irrational channels in which men's thoughts even then ran. In this last he runs down coals, which were getting into use in London—

"The soot from the coals dirties tapestries, clothes on the hedges, &c." "It has a great quantity of volatile oil, very sharp." Also—"We find that the most neat and polished silver plate, exposed to the air, becomes in a short time livid and foul; which proceeds from no other cause than those black atoms (the true colour of putrefaction) which stick unto them."

Bad as smoke is, it is fortunate that this happened, especially at a friend's house, where they were emptying sewers.

The chain of reasoning on every subject from the beginning of time till now, has been so much broken, that it is not surprising if we have not, on some points, kept alive all the knowledge that has been gained, or made additions with sufficient constancy. Chemistry, such as it was, medicine, and the knowledge of hieroglyphics, were alike lost together, and similar events must always occur if the custody is in the hands of a few. Nothing has more lamentably been lost than the arts; they have had no teachers, and had no historians. No writers seem to have thought it worth while to tell us how the carpenters, bricklayers, and potters did their work; their arts must have been devised with great wisdom, often after much patient observation and ingenuity, but the lesson only went to the next door. We could have spared many battles to have known the duties of the keeper of the streets in Rome, with his whole host of workmen, and how they worked. Indeed, minute knowledge in any department is scarcely to be got at the present day. Knowledge and habits are transmitted, as of old, by chance words of masters,—a mere scolding observation in the workshop at best. Now we know that a great advance is not made by mere work, and chance thought; the thought should be as regular as the action. What could professional men do without their theoretical teaching, their books, and their lectures, in which they learn to arrange their knowledge systematically, and by doing this sow the seeds of future advance? Teaching of a similar kind is as necessary for every art; every workman should have his lectures and his books.

Even now it is a fact that the men who work in our mills are educated to one action only; their fingers are taught the movement, and they live by that one movement; they are absolutely unfitted for any other after a time, and seldom have a chance of learning another. It is found impossible

to carry on a work of any kind in the place where no works of that kind are known, without long and laborious teaching and often much loss. The generations teach their next generations their own peculiar movement, and it might almost be expected that after a time children should be born which, like pointer puppies that point by instinct, should, by some instinctive movement, tie unseen threads in the air. The general system of work is in the lower stage, or imitative, and has only partially risen into the higher, or self-supporting independent stage, as the sciences and some more refined arts have done. We want theoretical teachers, that the men may cease to be mere attachments of the town or mill,—a serfdom inherent in ignorance and incapacity. It is from this want of the means of communicating knowledge, that the first steps of civilization have to be repeated so frequently, and we must be constantly learning the beginning, when we might be employed in unravelling the difficulties that constantly become more complex.

The learned discourse of Sir Kenelm Digby on the *Power of Sympathy*, from which I gave an extract, was published in English in 1658; and he might have been supposed to know better, but the great men even of that great century were not in all things on the shoulders of their predecessors, so hard was it to know what was done.

I obtained some time ago a little collection of old opinions in a small volume which I have never met but once, when I got it at a London old bookshop, and which, from a passage in it, I suppose to be either very rare or seldom read. It is by Philip Beroaldus. I may perhaps introduce here, somewhat contractedly, a part of his treatise on *Pestilence*:—

"Pestilence not only exhausts towns by constant deaths, but even whole nations, by a deadly disease. Some say that it is from the anger of God, some from the inclemency of the weather, and some from vitiated waters;—others from the noxious exhalations of the earth.

"Excellent medical men and philosophers have believed it to arise from the inclemency of the weather, that is, from the too great heat, cold, moisture, or dryness.

"So also every thing grows better where there is no excess of heat, cold, moisture, or dryness. But with any excess of these the force of the disease increases, and man and beast are attacked by pestilence. Whence it happens that inhabitants of moist and marshy places are liable to be attacked by this evil. But heat is especially destructive, whence some say they call the sun Apollo (*ως απολλυντα τα ξωα.*) But as the immoderate heat of the sun destroys all living things, so also its temperate heat removes all diseases, whence the Greeks called Apollo Αλεξικακον, the remover of evils, a name also given to Hercules.

"Some say that waters, vitiated and corrupted by fœtid matter, destroy health and prepare pestilence. For Aristotle says that the changes of water are very important, and Lucretius agrees to it in the line—

'Nonne vides etiam cœli novitate et aquarum.'

"Some are greatly tried by being at a distance from their homes; and Vitruvius writes, that grave and pestilent humors escape from the Pontine marshes. And, as Seneca says, noxious and pestilent waters lie in the depths of the earth, containing nothing but what is pestiferous and unwholesome to our bodies; these, after an earthquake, come out, and when people drink them, they cause pestilence.

"Some say that pestilence arises from the noxious evaporation of the earth, and that the earth is constantly giving out vapours; and certainly it is clear that the earth is not without a spirit, which it pours out abundantly for the growth of all vegetation.

"Avicenna also says that the corruption of the air is raised from the earth. Silius, also, in describing a pestilence, says that the vapour of the earth is pestilential, in the verse—

'Atque ater picea vapor expirabat in Ethra.'

Ammianus Marcellinus agrees with this; others think that the exhalation of the earth makes the air thicker, and so kills.

"Mathematicians think that pestilence and other evils come from the power of the stars, and chiefly the dog-star: with this the poets also agree.

"But most writers are agreed that pestilence comes from corrupt air, which spreads its evils all around—which kills the living who inhale it; for there is a constant interchange of air in us, and when without it, we are instantly killed; so when the air which we constantly breathe is foul and pestilentious, it must enter, by our breathing, into our vitals, and produce disease and death. Hence Virgil says,—

'Corrupto cœli tractu miserandaque venit
Arboribusque satisque lues et pestifer annus.'

And in like manner Lucretius says,—

'Et cum spirantes mixtas hinc ducimus auras
Illa quoque in corpus pariter sorbere necesse est
Consimili ratione venit bubus quoque sæpe
Pestilitas.'

And Ovid, explaining the poetic pestilence, thus speaks:—

'Ora patent auræque, graves captantur hiatu.'

Wherefore Avicenna, the most celebrated by far of physicians, thinks, that in pestilence, respiration and inhalation are diminished, and that odours should be used to mitigate the corruption of the air.

"Winds also, which are called flowing air, are the causes of pestilence; but chiefly the south wind, of which Celsus thus speaks:—'Pestilences occur in all winds, but chiefly in the south wind.' And Ovid also shows that pestilence comes by a south wind:—

'Lætiferis calidi spirarunt aestubus Austri.'

"Aristotle, in his *Problems*, says that the south wind makes bodies warm and moist, and therefore liable to corruption; which wind also is the cause of bad breath. According to

him also, men become heavier and weaker during south winds, and less inclined for food; whilst, during a north wind, animals have more appetite and become more robust. He shews also, that south winds produce a warm moisture in bodies; for those that are warm and moist are subject to fevers. Hippocrates also, in his *Aphorisms*, says, that a south wind dulls the ears, weakens the senses, causes headaches, looseness of the bowels, and a general moist, flaccid, and languid state of the body. Vitruvius also says, that the town of Mytelene, in Lesbos, was magnificently and elegantly laid out, but not wisely situated; when a south wind blew in it the people sickened, and when an east wind blew they coughed, but when a north wind blew they were restored to health. And our Pliny, who omits nothing, has comprehended all about the south wind in one word—"The north wind is the most wholesome of all; the south wind is bad, and animals are less liable to hunger when it blows."

More from Pliny and Albertus Magnus:—

"Nobody doubts that the dog-star, in whose mouth is Sirius, is pestilential and noxious.

"Among the causes of pestilence, also, is filth and excess of filthy substances, as lawyers* also in their writings have shown; for the filth of common sewers threatens to make the air a very pestilence, and this constant stream coming from a polluted source, gives out an odour not otherwise than infectious, according to the best writers.

"Among the causes of pestilence, also, I find want of food and change of food, which Cæsar the Dictator shews plainly in his *Commentaries on the Civil War*, writing that the people of Marseilles were much affected by a great pestilence, from the change of food; for when they were brought by a long siege to a great scarcity of provisions, they lived on old bread and bad barley.

* "Lawyers" here refer probably to the edicts already quoted.

"Hippocrates also allayed a pestilence that came to the Greeks from Illyria and Peonia by this remedy. He ordered fires to be lighted through the whole state, with flowers, with the most fragrant garlands and ointments, and perfumery, so that a purer, clearer, and fresher air should be spread about. Galen also says, that the air, becoming pestilential by respiration, becomes a poison.

"The same Hippocrates preserved many towns in Greece from pestilence, having stopped the windows, changed the doors, and let in the north wind by new windows; for which they gave him honours formerly given to Hercules.

"Also the learned Varro Terentius, when the island Corcyra was filled with sick and dead, stopped the windows, changed the doors, and let in the north wind by new windows, keeping his family and companions in health."*

We see, from these extracts, that a general idea of sanitary truth had risen in various times and places, sometimes marked by magnificence as the leading principle, sometimes by usefulness. The great water-works were for use, absolute necessity prompting the origin—munificent and enlarged feelings suggesting the scale. The same may be said of the baths, which, however, rose up to be a great curse to Rome, as the early Roman washing was more akin to the modern practice of the

* Phillipi Beroaldi de terræ Motu et Pestilentia, cum Annotationibus Galeni.

Perhaps I may be allowed to introduce here a short note. In the book above mentioned there are notes on Galen, or rather comments on his translators and interpreters. In speaking of *ναρκη*, he says—"Quod genus piscium, Galenus cæterique Græci Scriptores appellant *ναρκην* id interpres ineptè nimis vertit in stuporem, propterea quod Græcè *ναρκη* dicitur stupor, unde narcotica dicta medicamenta, quibus utimur in sectione membrorum quasi stuporem inducentibus, ut citra sensum cruciatus fiat sectio;" that is, "The kind of fishes called by Galen and other Greek writers *ναρκη*, the translator has very absurdly termed *stupor*, because in Greek *ναρκη* does (at other times) mean *stupor;* whence the term, in Medicine, Narcotics, which we use in cutting off limbs, producing a stupor so that the amputation is made without pain." This is another instance of the want of teaching even in a profession. The practice seems to have gone out, and there is no distinct record of the reason.

more careful classes: they washed the arms and legs once a day, and bathed the whole body once a week;* whilst the marvellously luxuriant baths converted many of the best citizens into idlers, and tended, amongst other things, to demoralize the inhabitants.

The importance of attention to wholesome food, and still more, the pleasure arising from luxurious dishes, was known to the ancients, but to a few only after all, as a general diffusion of any information was not to be found in early times. Even the delicate state of food cooked with softer water was known, as the wells were often preferred, on account of the hardness, I suppose, of the aqueduct water running from the limestone hills.

Their principles, however, were not very extensively carried out; their bed-rooms were closets, and their poor were numerous and degraded to a degree that none of our towns can in any way approach.

Although purification is a distinctly practical act, we see it taking a much wider range as an idea merely, and the act of purification as a ceremony. Washing before the performance of religious rites, seems to be a most natural action, but the ceremony of washing became a mere form with most nations. The priests of Egypt were rigorously clean, but their descendants, keeping the forms even among the laity, are by no means addicted to wholesome habits. The temples had always a reservoir of water about them; the mosques have water still, which water is a filthy stagnant pool, dangerous to health, but nevertheless a place where the form of washing is undergone. The Jews also have, from necessity, probably, adopted a mere form, dipping of the fingers and touching the body becoming a substitute for immersion. It is, however, frequently a result of idleness,—a mode of finding an excuse for an unpleasant act. Our Saxon forefathers had to be drilled somewhat in a similar way to the Easterns, and

* Smith's Dict. of Gr. and Rom. Antiq.

their priests were made to sing three hundred psalms as a punishment for eating or drinking what a cat, dog, mouse, or weasel had spoiled.* But after a time the habits of the priests became spread over the people, they became general,—necessary for comfort, and not ceremonial;—another instance of the manner in which a strict command becomes dissipated.

No doubt, from a sanitary beginning, the more observing classes, the priests, were accustomed to avoid swine and fish, both of the sea and Nile, as well as lentils, peas, garlick, leeks, and onions.† From some similar reason, they used pure linen next the skin,—a custom and command in India also.

Amongst the Brahmins, too, were forbidden "garlick, onions, leeks, and mushrooms, which no twice-born man must eat, and all vegetables raised in dung, red gums or resins exuding from trees, and juices from wounded stems, &c."‡

But with them, too, it became a form;—a Sudra might be purified with water touching the extremity of his lip, whilst the higher order, the Brahmin, is purified by water that reaches his bosom,—a Vaisya must take it into his mouth, and a Chitriya must let it descend to his throat.

I have no intention of attempting a regular picture of the progress of thought on sanitary matters, and shall only give a few examples of different modes of thinking on the subject in process of time. The plague in Italy gave occasion to many physicians to think of the subject, and diseases which attack men and the lower animals, as well as plants, took up the attention of many, introducing disquisitions on cleanness of food, cleansers of houses and of stables, arrangements for dry beds for cattle, some made of odoriferous herbs, as Bernardini Ramazzini counsels. The theories long wandering began to be put into shape, although Lord Bacon seems

* Sharon Turner's Anglo-Saxons.

† Wilkinson's Manners and Customs of the Egyptians.

‡ Institutes of Menu.

to have found it necessary to say, as a thing not well known even then, that the vapours found in crowded places in gaols, were poisonous. As a correct statement of the opinions of the period in their most advanced state, or rather, as the statements of a man who was beyond his time in most things, I may quote the following rather interesting passages from the writings of that philosopher, "*Sylva Sylvarum*," 328, &c. :—

"The inducing and accelerating of fermentation is a subject of universal inquiry. The means to induce and accelerate putrefaction are,—First, by adding some crude and watery moisture, as in wetting of any flesh, fruit, wood, with water, &c.; for contrariwise, unctuous and oily substances, preserve. The second, by invitation and excitation, as when a rotten apple lieth close to that which is sound, or when dung, which is a substance already putrefied, is added to other bodies. And this is notably seen in church-yards, where the earth will consume the corpses in far shorter time than other earth will. The third is by closeness, as in corn and clothes which wax musty; and therefore open air doth preserve. Fourth, by solution of continuity, as we see an apple will rot sooner if it be cut or pierced, and so will wood. Fifth, by exhaling—as in pestilences, where the malignity of the infecting vapour daunteth the principal spirits——and the humours, flesh, and secondary spirits do dissolve and break, as in anarchy. Sixth, is when a foreign spirit, stronger and more eager than the spirit of the body, entereth the body, as in the stinging of serpents; and we also see the spirits coming of putrefaction of humours in agues, &c. The seventh, by such a degree of heat as setteth the spirits in a little motion, as is seen in flesh that is kept in a room not cool; whereas in a cool and wet larder it will keep longer.

"914. The most pernicious infection next the plague is the smell of the gaol, where prisoners have been long and close and nastily kept, whereof we have had in our own time experience twice or thrice, when both the judges that sat upon the

gaol, and numbers of those that attended the business, sickened upon it and died. Out of question such smells consist of man's flesh or sweat putrefied. There may be great danger of such compositions in great meetings of people within houses, for poisoning of air is no less dangerous than poisoning of water. And these empoisonments of air are more dangerous in meetings of people, because the much breath of people doth further the reception of the ferment."

Becher also was thinking the same thing, with others in other parts of the world, and, after a long and rather imaginative passage, he says, in his "*Physicæ Subterraneæ*," Lib. i., sect. 5, cap. 1, n. 17, published in 1669:—

"Secundò, ejusmodi particulæ vario quoque modo alterantur, per putridas emanationes corporum sive vivorum sive mortuorum, hinc multi morbi contagiosi, refertque *Pancirollus in observationibus* vespillonem ex aperturâ cujusdam sepulchri, mortuum esse, presertim cûm cadavera insepulta jacent, nihíl enim magis inficit, quàm cûm aër iisdem inquinatur."

This asserts the danger of the putrid emanations of bodies, whether living or dead.

Closely connected with this is the theory of putrefaction and fermentation, both of ancient and of modern times, leading to the term *Zymotic*, for a class of diseases having the power of propagating themselves.

Fermentation in putrid bodies had, in fact, been much spoken of, as a cause of disease, until men were weary of the indefinite word. According to Kopp's "*History of Chemistry*," Willis, in 1659, first explained what fermentation meant, and referred numerous, if not all diseases to it. He said that "Fermentation was an intestine motion of any body, either tending to perfection or change." Stahl says, in Shaw's edition, 1730,—"Now 'tis manifest both to sense and reason that a body, actually in motion, coming to impinge against another which is moveable, though not yet actually moved, will communicate thereto so much of its motion as the proportion of the other's magnitude will allow it to receive."

Also—"Fermentation, which we define an intestine motion of mixed parts, that separates them in proportion to their mobility, and resolves or combines them according to its degree. So that this operation requires for its subject the parts of a mixt which differ in mobility, that is, have different degrees of tenuity; and in the next place it requires a certain management of this motion, so that it be inherent or intestine, and not *loco pulsive*."

This theory of fermentation was with great success applied to the solution of the food in the stomach, to diseases, and to contagion and miasms. Liebig has brought it forward in the same form, with the great power of illustration which modern science has furnished. His conclusions are very well known, and I need only give two sentences from his *Letters*, p. 209:—"All the phenomena of fermentation, when taken together, establish the correctness of the principle long since recognised by Laplace and Berthollet, namely, *that an atom or molecule put in motion by any power whatever, may communicate its own motion to another atom in contact with it.*" Then having referred the same principles to putrefaction, and shown, that in a similar way, disease may be produced and continuously communicated, he says—"Hence according to the rules of scientific research, the conclusion is entirely justified, that in all cases where a putrefactive process precedes the occurrence of an epidemic or contagious disease, or where the disease can be propagated by means of solid, liquid, or gaseous products of diseased action, and when no other cause for the disease can be discovered, the substances which are in a state of transformation are, in virtue of that state, to be regarded as the proximate causes of the disease." Letter 18, p. 230.

The whole reasoning, as given by him, is very clear and full, and it is one of the most singular instances of a theory made apparently very early and in the darkest periods of science, receiving illustrations now at the hand of science, with scarcely any difference of views, but only a clearer perception of the meaning of the words used.

Although there have been intervals of contradiction, the statements have been made early, but perhaps nowhere made so clearly as in a pamphlet written in 1721, entitled—"*An hypothetical notion of the Plague, and some out-of-the-way thoughts about it.* By Mr. Place." Speaking of infection, he uses the terms—"A body that works another to conformity with itself;" also, "perfect infection—the communication of specifical form and motion by matter of superior activity to some of inferior, that is, a substance fitly disposed or naturally capable of being wrought upon." And in few words—"Infection is the communication of motion by activity"—"among particles allied."

This seems to represent our knowledge of the subject as fully as anything yet said, and indeed more so, although it may not express, like the words of Stahl and Liebig, the mechanical law. If we go so far, we form a theory of the motion; if we adopt Mr. Place's remarks, we adopt a representation of the state of our knowledge.

It may happen that the extreme mechanical mode of stating this law is the right one, although not at present capable of absolute proof; and it may be remarked here that chemistry has gained by the application of mechanical laws in instances where affinity only had been supposed to act. As the most remarkable of all instances may be mentioned the failure of every method of explaining chemical combination, until at once made perfectly clear by what may fairly be called the Mechanical Atomic Theory of Dalton.

We may suppose the question of the production of disease, according to the chemical theory, to be put in this form, or to be illustrated by such reasons as the following:—

1. Permanent chemical compounds, gases or otherwise, are not capable of acting as infections, that is, cannot convey disease directly, although every gas is more or less able to cause death, the atmosphere excepted. Some decompose the tissues rapidly, and may give rise to other chemical

compounds, but they themselves are no infection, no zymotic disease. Ammonia, for example, has a great duty to perform; but in excess it exhausts action very much both in living and dead vegetation.

2. A true gas diffuses itself in the air, or in the gases, but all are soluble to some extent in water. All living bodies contain water; in fact, the motion, mechanical and molecular, necessary to life cannot be carried on without a liquid, nor indeed, generally, can substances act chemically on each other as many substances in the living body do, without the intervention of a liquid. Infecting matter is generally connected with diseased moist or liquid bodies, which are always to a certain extent giving off gaseous products in vapour.

3. Sulphuretted hydrogen, for example, is not miasma; it is deadly enough, but the sources of it are resorted to by invalids, which could not be the case were it a miasma. It may destroy the constitution, and produce other diseases which may have various effects: the same of carbonic acid, &c. Therefore in looking for miasma or infection, we are not to look for chemical compounds, and to decide on the presence of disease from these grounds. From this cause, chemistry has not carried us far in advance of the ancients, who did not know analysis.

4. The senses are not sufficient to detect miasma. Miasmas do not, at least always, possess a smell, or we are not able to perceive it. We do not smell what we are much accustomed to. In Germany there is the "Englisches Geruch," the smell that all English articles have, a smell of coal, I believe. In some districts every article is found to smell of peat, and this is especially felt on bringing them into a coal district.

5. The results produced by time, whilst the senses were unconscious and chemical analysis at fault, are to be depended on above all things. For example, bad air may injure important organs; the senses see the accumulated result. The chemical action is decided and progressive, whilst no pain is

felt. The senses in many cases come second in sensitiveness. Although chemical analysis often comes behind, it is capable, no doubt, of changing its place and going foremost.

6. Old writers, speaking of animal functions and of diseases, use the word "fermentation." Fermentation is the splitting up of a body into several parts, by a power within itself, or imparted to it by another body in contact with it. Sugar may give out alcohol and carbonic acid; but sugar also may give mucic acid and lactic acid. Some of it may form another body, fusel oil.

There are, then, some bodies which act on each other gratuitously, as it were, that is, they do not require either a proportionate amount of physical force or an atomic equivalent so as to act by quantity. Their power is apparently in proportion to their quality, not their quantity. Sulphuric acid decomposes common salt; when it has satisfied its equivalent, it is placid, and the common salt beside it is quite untouched. Not so with a ferment; it ends with the material to be decomposed,—that is, if sulphuric acid acted like common salt, it would set in motion the decomposition, so that it would never end till the salt were done. This is not exactly the case with the action of a ferment on sugar, because that requires a certain quantity; but of the action of a ferment on grain, for example, where the ferment may be reproduced as it is used.

7. Bodies dried do not decompose; moisten them, and they begin to putrefy.

8. The infectious matter of fever, plague, and cholera is not a true gas, it does not diffuse. It runs unequally, and without following the laws of diffusion, along streets and to distant towns. A true gas would go everywhere equally, unless it were taken more to one place than another by differences of wind and moisture.

9. The similarity of decomposition produced in one person by contact with another, is so analogous to fermentation or

putrefactive decomposition, that we have no stronger mode of producing identity of action.

Let us suppose an illustration:—The body is well, and decomposition goes on, producing certain pretty well known results by the action of life and all its subservient forces. One takes cholera, and decompositions go on in him also, but with different results. Instead of nitrogen being retained by the kidneys, they cease to act, and the bladder is empty; instead of the lungs decomposing the carbonaceous compounds, the gall bladder is filled with them, and the breathing is difficult. The fœces take the nitrogen. Its analogy to a reverse fermentation, or a diverted one, is complete. But there is no power of recomposing what was destroyed. It is a splitting up of particles of the bodies into parts; what is begun quietly goes on till all the material is worked up. If it passes to another person, it is a further illustration of the same action.

10. But a ferment acts by self-destruction. When it is done, what becomes of it? It converts the material next it, if capable, into a ferment also. We therefore conclude that infections increase according as the material to feed them increases; in other words, they convert all impure matter into infection, because it is fermentable in a particular way. In this way, then, various ferments would produce various substances. Or a substance putrefied might go into plague, fever, or small pox, just as the parts of the body do. Filth, therefore, is a conveyancer of disease, taking the lead of any infection which happens to have the reins in its hand at the time. No wonder, then, if all diseases disappear before a great disease,—one great ferment banishing the others. There cannot, in one liquid, be both the mucous, acetic, and alcoholic fermentations at once.

11. But they may come in succession; so after one disease another may arise on its remains. Is this the explanation of the rise of new diseases, or the history of the progress of some we know, which go on from stage to stage?

In this hasty sketch of opinion, I have chosen quotations not perhaps the best,—medical literature may be able to put them to shame by greater fulness; but chiefly because I thought them interesting, and also little if at all quoted.

We have seen that the notion of sanitary law has had its origin in the earliest history of nations,—that it is founded on simple, material truths, which it is easy to recognise by ordinary powers of observation,—and that it is supported in its conclusions by the more elaborated reasonings of scientific times. In itself it is not a science: we see in parts only, a distinct claim to logical sequence, uniting the beginning and the end; but it must receive the aid of many other sciences, and adopt their results. It may become a science: at present it includes the knowledge of many valuable arts. We can suppose it struggling through years of great darkness, groping onwards by mere instinct, and at last arriving at a state, if not of great power, at least of self-consciousness, although perhaps it will be disputed as to when that period was attained. At the time of plague it seems everywhere suddenly to have reared its head, and we may observe that it keeps its head erect continuously, whenever it finds that a continuous state of plague exists, or continuous causes operating against health. I am not encroaching on the province of medicine in speaking of this subject; the subject is a separate branch, it may be, of medicine, but equally a branch of chemistry, which certainly claims a right, as it has a power, of examining and explaining to some extent the action of the elements on man, and the means of rendering them serviceable instead of deleterious. It is a worthy study, because it enables us to remove many evils easily dealt with; it is also an ennobling study, as are all studies which shew that man is not of necessity degraded, and which give him hope even in this world of a higher and happier future.

I fear to go beyond the allowed bounds of the Society, and can scarcely therefore link, otherwise than abruptly, the foregone part of my subject with that which is to come.

STATISTICIANS have done so much to illustrate the painful condition of a great deal of the population of Europe, that vague notions of equal happiness and equal health among all classes have given way to the simplest facts, and I suppose we cannot pay any attention to the opinion of that man who will say that ignorance, poverty, and dirt, may enjoy life as much as he who has taken the greatest advantage of all the gifts of wisdom.

We have learnt the state of man in many things, but we must avoid supposing that we have arrived at the laws which regulate man's life. Speaking with reference to laws such as those mentioned in Quetelet's "*Treatise on Man*," we may say that he and such statisticians shew the laws which govern Frenchmen, Englishmen, or Belgians, in certain conditions; and that if the countries remain in the same state of education,—if they keep the same mode of government, and the same manufactures,—if they do not change their habits, and if no great religious or other movement seize hold on them,—then their bodily and mental health is in all respects likely to remain the same. But these men are all capable of immense change, as history proves. With us the sanitary movement has for a time been very active, and the knowledge of many necessary conditions of public as well as private health has been disseminated among all the reading public, so as to be now proverbially true; but their adoption by the unreading and unthinking has to follow, and that probably will not be done until public bodies shall have shewn a public example. This example is being shown, to more or less advantage, in some hundred places in this country, and the course of procedure in making a town to some extent less unhealthy, has been very nearly reduced to a system.

We have seen that all who think on the subject, condemn moist land, and although I think we may fairly dispute the reasons given, it may now be taken for granted that the somewhat sarcastic remark of one of the best of satirists had some foundation, that "the great object of a wise man is to

live on a gravelly hill." (Peacock.) Still the draining of land produces a benefit to us in every point of view. It improves the crops, it improves the health, and while it banishes vapours, it banishes probably superstition also, which sees the dim ghost in the mist of an undrained field. As I elsewhere said, every field has its own peculiar climate, and if we come to particulars, every portion of a field. We may say that every quarter of a town, every street, side of street, and house, has, from some circumstance natural or artificial, its own climate also, sometimes in a very marked degree. The thorough draining of a field is a ready mode of improving and equalizing at the same time every portion; a town will be benefitted in exactly the same way, as far as its natural position is concerned. A town surface is generally almost impervious to water, but even were it quite impervious, there are sources of water below, which supply town wells abundantly. Many towns are drained in this way by these wells, and this may in many cases be effectual, but of course a general plan is better. The most careful drainage of towns has been by sewers, but the evil from water in the soil has not been remedied. The Rev. Mr. Milner, of Penrith, has proposed a triple drainage, by which first the moisture of the ground is removed by tile-draining, refuse water being removed in the usual way, and flood-water from the surface. This offers many advantages; it gives a dry soil, and is a means, hitherto unused, of drying the soil. This plan might very well be extended beyond the town, and the land around the town might be subjected to drainage some time before building.

The drainage in the neighbourhood of Manchester has already been before the public in a paper by Mr. Roberton, read before the Statistical Society of Manchester in 1850. The mode of building at present resorted to deteriorates the neighbouring land from easily avoidable causes. This land lies waste, waiting for a builder: it is made of no use for agriculture, and offensive to the eye and to health. It would

seem a proper arrangement, that as soon as it is given up for agricultural purposes, it should be subjected to tile drainage, if that has been before neglected, and if within the limits of a town circle. But it must be still a more effectual way of ensuring efficient drainage if the men who build would prefer land which had been one or two years under the influence of drains. It is a wise provision of nature that organic matter which has travelled far under ground, should itself become so much transformed as to come out in an inorganic form; but there is frequently not enough of room for this process in the passage of organic matter from yards to cellars; and as the matter becomes somewhat stagnant, so to speak, we have frequently more than mere dampness under our houses. To draw it off as it comes is the best way, of course; and to drain the land before building, also, is still better, when the land is not very porous, and when it is in that very common condition of requiring one, two, or three years, in order to get the drains into a good running state. The outside of many towns, and of certain unbuilt portions of all our towns, are unsightly pictures of stagnant water.

The surface drain for rain water is perhaps not to be objected to in small towns; but when the distance to run is great, the accumulation by the way is great also; and instances frequently occur where even the sewers are not able to receive the water with sufficient rapidity, causing the streets to be flooded. Every spot of a field absorbs water, and the run is equal to the extent of field for some distance down through the soil; but a town has only a small strip down every street for the whole water fall, thus rendering the mere surface drainage for rain quite insufficient. If, however, the water from water closets were conveyed in a separate drain, as it has been proposed, we should gain many advantages, in all likelihood. To most persons this seems a very wild scheme, but it may be viewed quietly and without fear. At present all refuse water runs down the sewers, and there is only to be

found in them a very weak solution of decomposing matter. Of this water there will probably very soon pass 20,000,000 gallons per day through the sewers of Manchester. This makes a large stream, and collected it will be a small lake. Such an amount of water it does seem preposterous to lift, so as to cover land by irrigation. If this water were spread over a portion of land equal to 15,000 acres, it would be immensely to increase the rain fall. Now, the difference in fall of rain in London and Manchester is only 12 inches in the year; yet how very different is the climate! True, however, the water is not to be put on in dry weather, and it will therefore not increase the number of wet days; but it will increase the amount of water, and we know that in that case the time of drying the ground must be much greater. Also the manure is of course weakened still more, and the great excess of water acting rapidly upon it is apt to carry a good deal away. If put on with no excess of water, and allowed quietly to be absorbed into the soil, there is a provision of nature for absorbing the impurities and returning the water clear, if not perfectly pure. This might, I think, be effected more readily by using stronger liquids during wet weather, allowing the rain to dilute them. There would be also less to manage, less apparatus and expense, and no change of climate, from the enormous amount of liquid. The irrigation of land by sewage water is warmly recommended by the Board of Health in a very valuable report. If this water were not to be put on as liquid manure, but to be treated by precipitation, a plan which I think might succeed well, and be in many places to be preferred, then it would be found much easier to manage the liquid when concentrated. Used as liquid manure in moist weather, we have all the advantages of very dilute manure; we have the proportion of dry and wet days unchanged, and the state of moisture of the soil also unchanged to any extent worth mentioning; and as, wherever this liquid is transported, water is transportable, we have the means also

of irrigating, when such a mode of fertilizing does become advisable.

But would it not be expensive to have separate drains for removing the water in question from towns? The amount which might be calculated on is surely not more than a gallon a day for each inhabitant; but let us give two for 400,000 persons, or two and a half gallons, if it is wanted, making the whole 1,000,000 gallons. This quantity might be passed through by small pipes like private sewers, and at the very largest opening it would be but a very small pipe. But supposing the half were to be run off in three hours, which is a very probable occurrence, this is not a twentieth of the capacity of some of the water pipes. It is therefore by no means an enormous scheme.

The value of the substance detained cannot be disputed; we may fairly reckon it as capable of manuring land sufficient to feed all Manchester. This would seem to be the true quantity to be calculated on. It is not easy to say how much land is wanted to feed a man who eats beef and flour, but let it be only half an acre, we have 200,000 acres capable of being manured. I might fairly from this launch out into a very brilliant calculation, but it may lie at present. The plan might be carried out on low lands, of which there are many about Manchester, and that great expense of pumping, of water pressure also, and all its consequences, be saved. The liquid might be taken to a small reservoir outside the town, and distributed over the low grounds; if wanted, pumped up from that reservoir to higher grounds. But to pump by enormous power the weak solution of our present sewers through pipes, which are in fact a new water-works of a reversed kind, seems to be utterly hopeless of good.

As to the nuisance of having a reservoir of water of that kind near the town, it is better to have it of the smaller size, with the more concentrated material; it affects fewer persons, and it might be covered easily. It is also better than having

the nuisance spread by every house over the whole town, carefully planted, one piece at every man's window. Our streets are long rows of houses and long rows of cesspools, &c. in alternation; and we must remember that it is no matter how clean a town may be, if we have before our own houses, or behind them, a constant source of impure air as we now have; it is of no consequence what is around us if we are in a little unwholesome circle of our own. But let water-closets be universal, and this kind of drainage used, we should get rid of cesspools, which are still building in our neighbourhood; we should get rid of the moist part of middens, and of those enormous town middens which are a very curious feature of this city, lighted up at night and receiving stores from every quarter, carted in a manner not so different from the old Edinburgh system, so much ridiculed. Although we have made great efforts, yet it does appear as if the plan now used were one entirely out of accordance with the self-acting machinery of the age.

Let us consider what happens at present. The sewer water does not receive even a large proportion of the night soil; if the town were perfectly drained into it, how much more valuable it would be! But this small quantity pollutes the water almost as effectually as a great, that is, it pollutes it so much that it becomes unfit for all use whatever. A river is the natural drain of a country, but it is also a natural supply of water; and whenever the two characters interfere, the distinction seems to call for distinct channels. The amount of matter which will destroy the purity of a gallon of water is very small; 1 part of iron with 800,000 parts of water becomes perceptible with sulphide of ammonium. The impurities therefore which the eye does not see, may of course be in much smaller proportion, although some do exist in greater quantity still invisible. We may conclude, therefore, that by one grain of impure matter we may render impure a million grains, or about thirteen gallons of water. I believe that we may injure

much more with some common substances. We may, therefore, by using a very small amount of water, and sending it out impure, pollute a fine stream, so that all below us must be compelled to seek new sources of water. Now a stream is constantly increasing; it is a channel frequently of drainage all along the sides; we therefore destroy the valuable water coming from every point into the stream, the property of others, for some trifling use of our own.

It seems to me that the old laws about water may very fairly be revised in such new circumstances; and indeed, if the district is to increase in activity, a change both of the pure and impure water flow is indispensable. Now, it often happens that private parties must have water-works made for themselves; lodges, as they are called, are in abundance around us,—the water is either got out of the carefully drained ground, which has become valuable, even if it produced nothing but water, or it is got out of a filthy stream, which must be filtered and stored up at a great expense, and with a merely moderate result. The one grain has already spoiled the beauty of the one million grains of water, and it cannot be returned. But suppose the water were sent along the stream bank in a simple earthenware sewer, which would collect all that accumulated on the way, each man would have some justice, and the expense of lodges, which by no means improve a country, would be saved. This would be very appropriate in counties like Lancashire or Yorkshire, which have not only large towns, but a very dense manufacturing population living in numberless small villages, hamlets, and isolated houses and works, which are in frequent want of a method of draining, involving great expense when divided among a few. We should have a valley drain, a district drain, at a small expense, and the isolated spots around us would partake of the advantages of a closely-combined population. The amount of water actually rendered impure in print-works, dye-works, &c., is not great: the larger amount

which passes through is not much injured. The washing water, for example, is not rendered much more impure than on entering, whilst the dye-water can be emptied into a very small tank. The amount of water unnecessarily spoiled is far beyond what is used. Suppose 200 gallons are in a beck, and 50 becks are emptied in a day, (a very large supposition,) 10,000 gallons only are sent out impure by this means; whilst the same works could not get on with even half a million, and yet that would render many millions impure.

It is probable that a stream would, even when low, supply the wants of all in cases where there have been many separate collections of water; but if not, the union of the millowners in the valley would make a reservoir which would cause a constant supply; the interest of all would be the same, whilst now it is the interest of each to hurt his neighbour.

The appearance of our rivers would change, and the refreshing appearance to the eye and to the whole man, of a pure stream, would not be an imperceptible element in the result.

The substances which come from manufactories have all a great value. On examining the Medlock some time ago, I found the following:—

	Per Day.		Per Annum.
Potash	178 cwt.	.....	3,200 tons.
Soda	257 "	.....	4,640 "
Lime	940 "	.....	16,900 "
Magnesia	9 "	.....	160 "
Phosphoric Acid	71 "	.....	1,280 "
Silica	266 "	.....	4,800 "
Alum	18 "	.....	310 "
Oxide of Iron	124 "	.....	2,240 "
Sulphuric Acid	444 "	.....	8,000 "
Chlorine	151 "	.....	2,720 "
Organic Matter, containing 6 per cent. of Nitrogen	80 "	.....	1,440 "
Insoluble Matter, chiefly Silica, Alumim, and Iron Oxides	1,866 "	.....	33,600 "

In the remarks on this table in the Report of the Board of Health, it is said that the phosphoric acid here is capable of manuring 95,000 acres of wheat, or 184,000 acres of clover, 258,000 acres of potatoes, or 280,000 acres of oats.

Still this could not be made available, as it at present flows, with any moderate expense, and the best way is without a doubt to separate it before being diluted, instead of attempting to separate it after diluting. It is not even necessary to carry all the matter into a reservoir below Manchester, but it might be used in its passage downwards wherever opportunity occurred, either for preparing the manure dry, or putting it on the soil as liquid manure. From one of these refuse substances, the waste soap, Mr. A. Mc. Dougall has already prepared marketable commodities of great beauty and value.

The population is becoming so close that it does appear time that we should cease to act as individual towns only, and endeavour to act as a collection of towns, which the district certainly is. This could not affect the Manchester water supply, but only its drainage; it would, however, affect the supply of numerous smaller towns and villages, and many works. Every valley would become united in its economy, as seems to be the most natural method. The impure water running along river courses would not very much increase; it would be used along the line in part as manure, and the mode of carrying it forward need not be an expensive one; a simple stone or brick channel covered would be enough. If we examine the sides of a stream, we see drops trickling down from the banks, growing larger and larger until they have force to fall into the brook; if we examine the banks of the Thames, of the Irwell, or Medlock, we see the blackest and most impure trickling drops, which imitate the others in falling into the stream, but not in improving it.

This mode of collective water supply and drainage might be carried on to a great extent, that is, between villages,

towns, and works, without making any extensive change in the water-closet system essential, but to make it complete that change is essential. The mode of building here offers many advantages in a sanitary point of view; the houses are low, they occupy a great deal of space. But if that space be not clean, of what advantage is it? A yard behind a house may be made an agreeable spot, but we do make them by no means agreeable or wholesome. There is scarcely a row of houses to be found where the backs are not actually unpleasant, not to say disgusting, to look at; it is, in fact, the habit of the country to have the backs of the houses filthy more or less, generally damp, and instead of a place for play or for air, mere nuisances. No one living in a town can, with the smallest degree of satisfaction, look out at his bedroom window at the back of the house. It is not wholesome to leave the window down, and it is also unwholesome to put it up.

The wide-spread streets and small houses in Manchester might be made the most wholesome residences, by adopting a plan long recommended by the Board of Health, and which is now past a mere opinion. I have seen it abundantly tried in Scotland, where, in a country which has suffered from being behind in cleanliness, an effort has been made which is likely to put them a good deal in advance. There, however, the great disadvantage of living in flats has to be overcome,—a very great one, I believe, and one which I am sorry has been adopted in model houses in London. Such houses never appear to me to be so well ventilated; there is the large space of the staircase wanting, and there is its ventilating power in sweeping from below up to every room and through every window. But they are adopting the water-closets even in small houses of ten or twelve pounds rent, and they are gaining the advantage. The yard behind is kept clean, and clothes may be dried in it; it is not, as before, a place to be actually feared. To the water-closet they have added a bath, and over it a shower-bath; the whole is compactly placed

in a small closet out of the lobby. The whole of this has been done for £10. Water-closets have been put up in England, water supply introduced, and drainage effected, at about £4. for each cottage. In several cases at Rugby, Croydon, Barnard Castle, and Tottenham, quoted in a Report of the Board of Health, the combined expense of all the work did not amount to above 1½d. per week in the highest.

Even in large houses silver cannot be kept in certain parts, generally at the back of the house, because if a water-closet exists, it is not for sanitary purposes, but simply as a luxury, whilst the yard is made as bad as that of a house even of the poorest classes. Indeed the water-closet is often a decided nuisance, draining, as it does, into a cesspool. I was looking at a row of houses the other day, about twenty in number, of a good appearance, and with many modern improvements, but I was surprised to find that every one had a large cesspool behind, so that there were twenty cesspools all in a row, just below the bedroom windows, beside the middens. This was not enough: there were also for every four cesspools a pump. It would not be convenient without this arrangement, as the cesspool would fill up too rapidly, if not pumped out.

Now I wish to speak very distinctly on the water-closet system, that the subject may be more attended to here; and as the early supporters of the name of this Society have great weight, I shall give some of their opinions on the opposite system. In a communication made to the Manchester Board of Health in 1796, Dr. Percival, whose tablet stands behind our President's chair, says—"The first object of the Board of Health is to obviate the generation of disease. Under this head are comprehended—The inspection and improvement of the general accommodation of the poor; the prohibition of such habitations as are so close, noisome, or damp, as to be incapable of being rendered tolerably salubrious; removal of privies placed in improper situations; provision for white-washing and cleansing the houses of the poor twice every

year; attention to their ventilation by windows with open casements, &c.; the inspection of cotton mills, or other factories, at stated seasons, with regular returns of the condition as to health, clothing, appearance, and behaviour of the persons employed in them; of the time allowed for refreshment at breakfast or dinner; of the number of hours assigned for labour; and of the accommodations of those who are parochial apprentices, or who are not under the immediate direction of their parents or friends; the limitation and regulation of lodging-houses, or the establishment of caravanseras for passengers, or those who come to seek employment unrecommended or unknown; the establishment of public warm and cold baths, provision for particular attention to the cleaning the streets which are inhabited by the poor, and for the speedy removal of dunghills and every species of filth; the diminution, as far as practicable, of all noxious effluvia, such as those which arise from the workhouses of the fellmonger, the yards of the tanner, and the slaughter-houses of the butcher; the superintendence of the several markets, with a view to the prevention of the sale of putrid flesh or fish, and of unsound flour or other vegetable productions."

At the fifth annual meeting of the Board, May 30th, 1800, it is said, that "fever is continually generated in filthy lodging-houses, in crowded factories, in damp cellars, and in places exposed to the baneful effluvia of dunghills, from sewers, and stagnant waters."

And on December 10th, 1801, Dr. Bardsley read a paper containing the following:—"1st. Be careful to avoid living in dark, damp, and confined cellars, or in back streets, adjoining to privies or heaps of offensive and corrupted matter."

Then the Board adds, (and I may remark here that Dr. Henry was also engaged on this Board,)—"In many parts of the town, houses are erected with their fronts opposite to open privies, and joining to accumulations of every kind of filth, and where the space between the front of one range of buildings and the

back of the other is so narrow as to prevent the circulation of air and free admission of light." The landlords of such houses are much blamed by the Board.

There is great scope in this list, and already many of these things pointed out have received attention. There is already, in the Public Health Act, a prohibition of all very bad cellars, and arrangements for purifying very dirty houses. There is an inspection of mills, markets, slaughter-houses, and such places as may become nuisances. There has also been an attempt in Manchester at public baths and wash-houses; but the question of dunghills has been very curiously handled. It is supposed that if a dunghill has a wall round it, it is then quite clean, because it becomes an ashpit. Now we know that the evil can be very little diminished by this means. It certainly is diminished, because the nuisance is to be calculated by its superficial area; but it is so far from being a final sanitary measure, that it may be considered as the rudest form by which nightsoil can be prevented from actually occupying the ground on which we are to walk. The actual nuisance can no more be confined by a wall, than the spirit of a man by a soldered sarcophagus.

The evil to be feared is not merely that intense accumulation of odour which so affects the senses, and which we avoid in accordance with a very old sanitary law, the feeling of disgust. What we want to avoid is that diluted impure vapour which, steaming up as it does from 60,000 to 70,000 centres, must inevitably be found pervading every cubic inch of our atmosphere. Now it so happens that these places are generally behind the house, that part of the house which it is most important to keep clean,—where the daily work of the house is going on,—where the door is most frequently open,—and where there is the supply of air for the whole house. The whole house may fairly be said to be fed from the back yard, as houses are built, and thus it happens that when a house is large enough to allow room, a door is made solely to prevent

exhalations from the kitchen and yard. It is well known how rapidly without this door the house becomes aware of what is getting cooked. This part of the house, too, is damp generally. Streets are formed at the backs of houses of a very unwholesome kind. They are much worse than the old towns consisting of narrow lanes. Here there is room only for one person to walk conveniently, and as there is a high wall, and all the ashpits are arranged close to doors opening into these streets, we may be sure that there is behind our houses places where there can be no comfortable living. We must really avoid this system, or there must again be a sanitary inquiry into the system of nuisances. The walls there are generally too high; there is no need of such height, and with it the places never dry well; even in a burning summer, large yards will not dry when the walls are high. I believe that this part of the house should be as open and dry as the front, and that it may be made just as wholesome, not by more expense, but by more judgment. There is of necessity at the back of the house a good deal of work, of washing, and cleaning; now wherever water is used, there ought to be free access of air and good drainage; this is the only way of avoiding the bad effects of what is called dampness.

We may fairly conclude, I believe, that the backs of houses should be made open, clear, and dry; this can be done by preventing the high walls now in use, by making a dry ashpit, into which no nightsoil shall be put, and by having such drainage as will prevent the dilapidated state of the pavement of those narrow back streets, which ought to cease as such, and be made merely into open passages, at the most with open railings. If it is said that people like a suitable separation from their neighbours, then I may add that the highest walls now used are really no separation, as they are all overlooked by the windows of the next houses. There would be room in the yard for a water-closet, which might either open into the yard or into the house, and for a bath, such as is

now so common in Scotland. These baths and water-closets, very curiously, do not make the house any dearer; on the contrary, I think the houses are better than before, at the same rent, leaving these extra conveniences and luxuries out of consideration.

I am often sorry to see so many of the houses building around us so carefully imitating the faults of previous houses, and sometimes adding one of their own. Little talent has been applied to the building of small houses in our neighbourhood, although we find that the subject has not been neglected, especially in agricultural districts, which we sometimes are apt to regard as the dark corners of the earth. Drawings of some will be found, very neat, in Morton's *Encyclopædia*, but the expense is not given; it would, however, be different from the same building in Manchester. One thing seems never to be looked at in building houses, namely, the size of a family. Apparently, a poor man is supposed to have only a small family and a rich man a large one. It is true, to some extent, as far as domestics and visitors are concerned; but there ought certainly to be houses for working men with large families, not finished more elegantly than those now made, but merely extended, so that the increase of rent might be as small as possible; now, however, a house rises in its style and finish with the number of its rooms, and the man who needs it cannot have it. An extra bedroom might be added without costing more than a few pence of rent per week, whereas he would probably have to pay some pounds a year, perhaps equal to from two to four shillings a-week, to get the same accommodation, causing him also to go into a different class of street, and into a house demanding by its appearance a style of furniture which he cannot pretend to. I have often marvelled at this want of accommodation.

It is well known that the poor man pays most for his house, and we would think it should therefore have the most care. Unless the position and all the surroundings of a house be

clean, cleaning within is vain; and whilst this ought to be insisted on, the internal arrangements are not to be forgotten. It is exceedingly difficult to find a warm house; the walls are becoming very thin, and it would be much better if, instead of such brick walls as are used, mud or gravel walls were substituted; but better still if thicker walls were built and hollow bricks used, if even clay should be found too dear. This is a very wet country, but we have plenty of coals; still these coals do not warm us so much as the few chips of wood in other colder climates. Count Rumford long ago spoke of the great evils of roasting one side and freezing the other, and laid down some good principles, which are only sometimes attended to. One is, that the opening above the fire into the flue should only be four inches wide: we make a great cavern like the kitchens in old castles, and the heat runs rapidly up with a strong current of air.* A small chimney-pot is put at the top to prevent draughts, but by making circular flues, which would be done cheaply, we could have the whole course of the air converted into a chimney-pot, and smoking would cease. These could be made as cheaply as common brick flues, which smoke so much, being so difficult to heat, and which are so rough as to accumulate a great deal of smoke above.

Besides that, we have the principle of the stove, the sand bath, the water bath, and the air bath, by all which means a room may be very well heated at a less expense of fuel. Why is this not applied to small houses? The same fire which cooks, might heat air; the fire-place might be between the kitchen and the lobby where there is one, and the warm air and warm water be sent up stairs. I am sorry I cannot give a proper estimate of this, but the price of iron is such as to prevent it being a large sum, whereas, ultimately, it would be cheaper. For the sake of warmth, absolute want of ventilation is resorted to. An instance came before me some time ago, when I was sent for to look for poison in the stomach of

* With certain modifications this latter plan may be made the best.

a child: I found that in a fine country, with fine air and in a healthy place, three people had been nearly stifled, and one, a child, had died. Where there is not a warm atmosphere it will be sought for at the expense of health; and both here and in the snow-huts of the north, people will crowd together for the first demand of comfort—warmth. It is vain, as it is also absurd, to tell people to ventilate, when it simply starves them. Experience tells us that warmth will not be dispensed with, and all classes will be found to stop up ventilating holes if they send in a current of cold air. I consider, then, that the first step to be taken towards ventilation is warming. The modes of warming are already known, and it is known that by hot air or water it is done more cheaply than by open fires. Then why not do it?

If the temperature were raised only four or five degrees on an average during the year, it would be a difference equal to the warm south-west of England, and the south-east. No doubt many persons ask the question—Why should working men have such luxuries, which they have not been brought up to? It has been abundantly proved that they are not luxuries, but that these people have a less chance of life; the means, therefore, of ameliorating their condition become necessaries of life. They do not live well enough; the result proves that they have not become accustomed to their condition. It has been shewn abundantly that they yield to it simply by dying. Dr. Percival, whose observations before the Board of Health were always very comprehensive, remarked of the state of infant labour at the time, (1796,) "that it tends to diminish future expectations as to the general sum of life and industry, by impairing the strength and destroying the vital stamina of the rising generation," &c.; and Dr. Ferriar, in remarks to the same Board, said—"The obvious extension of the cares of the committee to a superintendence of the morals of the poor, as intimately connected with the preservation of their health, comprehends a variety of most

important objects, which cannot be obtained without application to the legislature of the country." How right these men were, and how painful the consequences of waiting longer before making enactments, has been seen by the inquiry of the Health of Towns Commission, which has shewn a great diminution of the length of life in large towns in Lancashire, whilst the country in general was actually increasing in strength.

The infant labour mentioned has been put a stop to; the other evils are to be prevented before they violently seize hold on us. The subject, so far now from being settled, is only getting fairly begun, and it will be no easy matter to complete it. We hear that a few cottages in the country may be infected with disease from filth, even on a hill-side; this will, therefore, give us some indication of the great care that is necessary in a town. The whole population, too, has changed its kind of work in sixty or seventy years, and their ordinary lives and habits have not sufficiently changed with it, as the progress has been made in those things chiefly which have made the means of improvement, not the improvement itself.

One of the greatest sources of impurity in the atmosphere is, of course, the smoke; and it is the most difficult to deal with. The black portion is bad enough, but the portion which remains when the black is thoroughly burnt is also very far from being a wholesome gas, containing, as it does, much sulphuric acid and sulphate of ammonia. This is, even in small quantities, injurious, and it may be made clear to the senses by observing the action on colours; it reddens, for example, vegetable blues rapidly. When the sky is open, there is a fine clear air in our streets; the gases seem rapidly to follow the laws of their diffusion, and they leave at a rapidity which almost satisfies theory. There is then, no doubt, a constant flow of air into the town, along all the streets and roads, to make up for that great current which is

continually rising up into the atmosphere. If the air were constantly clear, we should then have very diminished evils of the kind, as this constant ventilation of the town would take place; but when it is clouded and moist, an entirely different state of things occurs. The acid and other impurities become dissolved in the moisture, and the black parts of the smoke become wet and heavy. At this time the air becomes very acid, and the atmosphere, as we approach the more crowded parts of the town, becomes sensibly deteriorated. This must have been observed by many. If the day be foggy, this takes place in still greater force, and these floating particles of liquid must have a strong influence on those who are subject to coughs, or are otherwise delicate, being, as they are, solutions of acid and acid salts. This is one of the ways in which we suffer from a moist climate, and it is another reason why we should do all we can to dry it, by removing the water when it does fall, and allowing only that which is pure to be exposed to evaporation.

According to one analysis of a coal used in Derbyshire, which is rather below what is a good deal used here, I believe, there is one quarter of a ton of sulphur obtained from 100 tons of coal burnt. This would give 15 cwt. of strong sulphuric acid, which itself would be a great deal to exist in the atmosphere at a time, if we take Manchester as four miles square, and suppose a space 300 feet high; but the calculation is of little value unless we know the amount of coal consumed. I do not know how much is burnt in one day, but it will be seen from this to how great an accumulation of bad air we are exposed, whenever an interruption occurs to the natural ventilation of the town. This interruption occurs not from entire calmness of the atmosphere, such a thing is rare with us, and if it did occur in clear weather, would not be a great inconvenience, unless it lasted long; on such occasions the gases escape readily, especially when with clearness there is warmth. But the interruption to ventilation

occurs by moisture, partly the natural moisture of the atmosphere, sometimes the removable moisture of the ground, or the accumulated moisture from works and private houses. The 100 tons of coal would give out, at a low estimate, 24 tons of moisture or water; with 1,000 tons this would rise of course to 240 tons of water.

I am sorry I cannot say how this evil is to be dealt with. It has been gradually decreasing on one side, whilst it has been increasing on the other; the amount of coal used for the same work is much less every year, from the improvements in boilers and engines, but the actual consumption is increasing from the amount of work being so much more increased. No doubt the burning of the smoke would greatly improve the atmosphere. I mean the burning of the black portion; and this should be more attended to. I fear it is becoming less thought of than it was. The air would then be clear, and the gases would rise more readily. But the removal of the sulphurous gases will not by this means be effected properly. Good drainage of the country around will improve the air and remove many fogs; we must look to this as another means, and perhaps the time may arrive when many persons may be induced to use coke instead of coal, and especially purified coke, such as, I am informed, Mr. Crace Calvert has been successful in making.

The minimum of evil will then be gained, as far as the burning is concerned, and another minimum must be sought for as far as the mode of using the heat is concerned. The most complete mode, however, of using coal, would be to take out its power without combustion, quietly oxidizing it, if possible, in a galvanic battery, and at a low temperature; taking the power from it, as Mr. Joule shews the power to be taken from zinc treated in this way, instead of by burning. This, however, is beyond our present means, at least at a cheap rate. Some different mode of burning coal is certainly desirable, from the enormous quantity of solid material

in the air carried up by the draught of the chimneys, falling down in abundance everywhere over the town.

That the mere burning of the carbon of the smoke is not enough for health may be seen from brick-kilns, although perhaps they do not present a very correct instance, as they give out also the gases from burning vegetable matter in the clay. Still the sulphurous vapour is distinctly recognizable, and they may be mentioned as an example of one of those things that ought not to be allowed to infect a neighbourhood. There has been no fair attempt to improve the mode of burning, and there is no appearance of any attempt to get the clay in such a way as to let the ground be agreeable to the eye, whilst above all things there is no attempt made to put it in order when brickmaking has ceased. There is surely no inherent impossibility in using high chimneys, although some attempts have not succeeded, and as to draining the ground, it is a self-evident duty. It is a curious thing, that whether through the cunning of the brickmakers, or a very common perversity of reasoning, it has come to be actually believed that it is wholesome to breathe the vapour from the kilns.

I have been saying that it is impossible to have a complete drainage as a town; we must have the whole district under one system, simply because whatever we may be called, whether Manchester, Bolton, or Bury, we are subjected to the same evils, and must work together for the same remedy. The same is the case as to manufactures. If we put out of the borough all disagreeable manufactures, we only send them to our neighbours, who may, after all, be so near us that we shall still feel the mischief. And where are nuisances to be sent? The whole of South Lancashire is like a town, some of it thinly peopled, but on an average a well-peopled town; so of other places. There has been a constant desire felt to avoid large towns; and very numerous small ones, from this as well as other causes, have sprung up; the former, however,

cannot be avoided without much inconvenience. It was to be supposed that when railways sprung up, large towns would diminish, as there might be a scattered population along the lines, thus avoiding concentration, the great need of large towns being done away with. This is certainly becoming more and more probable, and it is not impossible that the time may come when the work alone shall be concentrated, and the population greatly scattered. This would be a much better result than concentrating the population and scattering the work. Whatever mode be taken will be gradually evolved out of the instinctive feeling of the people, the convenience of living and of working. But the law gives us a right to remove nuisances, so that we may live in comfort. And now the question comes—Shall we remove them? If so, to what place shall they be removed? and which shall be removed?

Works here are not like works in Kingston or Richmond; we cannot afford to treat them badly. The work which we remove may take a whole street after it. It goes to a district near us; it settles down under few or no restrictions; it is a greater nuisance than ever to all its workpeople, who settle down in muddy land around it. The good done is often questionable, the evil is frequently unquestionable. There are, in fact, no works which are not more or less nuisances in the town, and as the town gathers round them, and will probably continue to gather round them, wherever they go, they must be considered as its nucleus, which it is really absurd to grumble at.

It seems to me, therefore, that all we can do in such cases is, first to see that every work is carried on in the most sanitary method which can be devised; secondly, to make regular investigations into the capacity of improvement of which some are capable. If any one is incapable of improvement, let it be removed; but if it can be improved, let it be so, remembering that if removal be a necessity in any case, it is by no

means good as a general policy. This town has sometimes done this certainly, but there has been no efficient mode of finding out the truth: and with the most laudable desire of doing right, the guilty have not suffered much more than the guiltless.

The great works of the town—the mills and foundries—must be preserved in it; that is an axiom. We could not remove them; but some are offensive to pass, and some are not so,—each should be kept up to its standard. Their lowest proportion of nuisance may therefore be called the standard amount which is tolerable; all others, therefore, have the same right to the same amount at least, and cannot justly be removed until they exceed this.

If works are removed, I think that even then, if at all in the district, or in any well-inhabited district, they should still be obliged to keep up to some standard of cleanness, interfering with liberty as little as possible. But to prevent the district around us from becoming unpleasant, it is necessary not to send all the nuisances outside of us, as the better policy, I believe, is to encourage by all means the growth of country houses, and the dispersion or diffusion, in opposition to the concentration of the population.

On account of the length to which this paper has grown, I leave many subjects of importance untouched. Individual nuisances might be spoken of if it were a paper on the sanitary condition of Manchester. At present, when speaking of the town, I confine myself chiefly to the proposal of a complete and united system of draining the district, with all its towns, villages, hamlets, works, and isolated houses, carrying away with it the necessary refuse of every house, making an entire reform in that important part of all streets, the back part of the houses, removing the obstructions to drying and ventilating, and making it look at least not disagreeable; and to calling attention to the mode of building smaller houses,

which have not hitherto had sufficient conveniences; and to warming, as essential before ventilating, a point which architects seem to have entirely neglected, at least in small houses, and which the sanitary movement has not yet made prominent.

It would not be a scheme too great to be carried out by a great capital, and its action would simply be thus:—

1st. All purely agricultural drainage would be separate from impure, going down to the nearest brook or river, adding to the supply of pure water, which would maintain its natural course. These drains would gradually increase as each proprietor drained his land. In fact, they do so now, but the system is not united.

2nd. Every house and village would be drained, the drains avoiding the agricultural drainage, and carried down into a separate conduit for impure water, which would pass down the valley, increasing constantly as a large town came in the way, but probably not increasing so rapidly as the towns, because a good deal would be used for agricultural purposes on its way. In this manner an immense track of ground would be brought near to a supply of liquid manure.

3rd. The streams would be left clean, and the water would be used as it came down, instead of one gallon being used and sent back to render impure a thousand others, as at present is universally the case.

4th. As this gradually increased, the water-closet system would be gradually increasing also, and in process of time it would be found profitable to make separate sewers for their contents. The result would be, that 70,000 middens, the number having increased very much since the last sanitary movement, would be removed from the town, and hundreds or thousands from all the district around us, whilst the ground would be made healthy to produce food, instead of the air being made unhealthy to destroy its legitimate effects.

5th. As to building of cottages, it would be well that some one would make a fair beginning and example; it may be doing, whilst we are ignorant of it. But if so, it shews the great want of a proper mode of diffusing information in the arts, and the necessity for a mode of teaching—a Mechanics' Institution, properly so called, which has never yet been established. But this requires a separate treatment.

6th. All these things could be done readily in this county, if Manchester encouraged it, and it would be a fine lesson to many others. As inquiries shew that these towns around us require more attention to minutiæ than towns not manufacturing, some, or all of these things, besides many others, are necessary.

In conclusion, I know that Manchester has done a great deal lately in regulating its affairs, but it must not be forgotten that a great deal, if not all, was rendered essential, owing to the previous enormous neglect, which it showed in common with many other towns;—that the step it has taken was necessary, in order to prevent evils which had become alarming, and which threatened to be worse, and that the improvements made, have not yet been sufficient to raise the average life to the level of that of many other places.

IV.—*Memoir of the late* Mr. John Just, *of Bury.*

By Mr. Jno. Harland.

[*Read January* 11*th*, 1853.]

When honoured by an intimation on the part of this Society, of its desire to have some memoir of its late corresponding member, Mr. John Just, a ready compliance with the wish that I should prepare a brief sketch of his life and character, was given—from no confidence of being able to do him justice; but rather from the feeling that I had no right to decline the sacred duty of offering a tribute, however feeble and inadequate, to the memory of my departed friend.

Before commencing the brief and imperfect sketch thus undertaken, permit me to observe that it is of necessity limited to what may be called the external biography, the outer life, of the man. Apart from autobiography, a man's own portrait of himself,—all biography which professes to be internal, seems to me to be not a little presumptuous. For one man to attempt to represent the life's thoughts and feelings of another, to depict all those countless attributes that make up the personal character, the deep inner being, of a human individuality,—this implies indeed a rashness so great, that the most gifted may naturally shrink from attempting the task. To say nothing of the differing powers, the various capacities of men; even to overlook the peculiar incapacity of some minds for rightly comprehending a man with whom they may be in daily and intimate intercourse;—we cannot forget that there must lie hidden in every human being, many

secret sources of life and motive, many deep founts of feeling and affection, which are only rarely, if at all, revealed even to the closest intimates, the oldest and most valued friends. Wise as beautiful is that saying of the Old Scripture—"The heart knoweth his own bitterness, and a stranger doth not intermeddle with his joy." This difficulty (not to say impossibility) of interpenetrating another's mind, is greatly increased, when, as in the present case, that mind is veiled in the folds of a shrinking and reserved disposition. Were it asked or expected, then, that our deceased friend should be portrayed as he was, in all his relations to the unseen world of thought, no less than to this visible and palpable world of action, the task must have been relinquished from a fitting consciousness of inability to perform it. All that can be offered here, is a brief memoir derived from personal knowledge and observation, and the recollections of friends and kindred—a record of the outer life alone, of what the man said and wrote, accomplished and suffered, rather than of what he thought and felt, struggled for and aspired after,—in short, a sketch not so much of what he *was*, as of what he *did*.

Diffidently is this rendered to the Society, with the sole desire to place before it, however defectively and feebly, a true and faithful record of the life's pursuits and labours of its departed associate. For no tribute can be honourable to the memory that fails in fidelity or departs from truth. If less of direct eulogium be made than is felt by the writer, or is thought meet by this Society, let it be attributed to no coldness of regard, to no blindness to rare merit; but rather to a desire to shun any semblance of the inflated exaggeration of the French *éloge*, and to keep to the honest simplicity of a plain English memoir. Our loss,—the loss of science and of society,—will be far better estimated and appreciated by a bare record of what our friend laboured to effect, and what he really did accomplish, than by the most laboured eulogy or highly-wrought panegyric.

The late Mr. John Just was the eldest son of Mr. Jonathan Just, formerly a respectable and industrious farmer, residing at the village of Natland, in Westmorland, two miles south of Kendal. The family had been long settled there, and the subject of this memoir was born on the 3rd of December, 1797, in the same house in which both his father and his grandfather had resided, the farm having been in the occupation of the family for nearly a century, and it is still tenanted by a brother. John Just obtained the mere rudiments of an English education at the endowed school of his native village (then kept by the late Mr. James Ward, an artist of some repute); and as he grew up, strong and robust, he was employed, when not at school, in ploughing, harrowing, and in such other agricultural pursuits as the sons of farmers usually follow. He early manifested so intense a love, and so great an aptitude, for learning, that he was afterwards, when about fourteen years of age, sent to the grammar school at Kendal, where he commenced his classical education under the able tuition of the late Rev. John Sampson, its master; remaining in this school about twelve months. It is but right to state that, in after years, Mr. Just always spoke in grateful terms of Mr. Sampson, to whose care he acknowledged himself indebted for all his mathematical knowledge, in which he was no mean proficient.

Whilst here, the late excellent Carus Wilson, Esq., of Casterton Hall, near Kirkby Lonsdale, the owner of the property of which Mr. Just's father was tenant, had frequent opportunities of seeing the boy and judging of his talents and disposition; and, finding him to manifest so strong an intellect, and so remarkable a desire to acquire various knowledge, that gentleman liberally took him into his house, when he had nearly completed his fifteenth year, and sent him at his own cost to the neighbouring grammar school of Kirkby Lonsdale for about five years. While an inmate of Casterton Hall, he manifested his versatility of talent, and his

constant desire to be useful, in various ways. For instance, he amused himself by engraving the cypher upon a great portion of the family plate there; and brought his taste for the mechanical arts, and his skill in several of them, to bear practically in the manufacture of several barometers, which he constructed, graduated, and engraved himself, and which are still possessed by friends of his youthful years, who highly value them, not only for the sake of the maker, but also for their accuracy and excellence. One gentleman informs me that the best barometer he ever possessed was wholly made by Mr. Just. At the Kirkby Lonsdale School he completed his scholastic education, under the care of the late Rev. John Dobson. During this period, the change of his circumstances, especially the leisure he possessed and the exemption from farm labour, greatly favoured his studies, and he continued to be distinguished for indefatigable industry and for good conduct. At this early period of his life he manifested a taste for antiquarian pursuits, by commencing his investigation into the Roman Roads in the neighbourhood;—doubtless stimulated to this branch of archæological inquiry by the existence of a Roman station at Natland, in a bend of the river Kent, called the Water Crook, supposed to be the site of the ancient Concangium, where the ramparts of the square fort are still discernible, and various relics have from time to time been found. While a pupil at Kirkby Lonsdale, he took advantage of a holiday one winter's day, and walked thence to Borrow Bridge, on the Lune—a distance of sixteen or seventeen miles—to examine the fine Roman remains still existing there, and home again in the evening. Those only who know this mountain road can adequately estimate the arduous labour of this undertaking.

Mr. Just possessed a remarkably retentive memory, and whatever he once read he seemed thoroughly and permanently to make his own. A somewhat amusing instance of

this faculty is related by a gentleman, once a pupil in the Kirkby Lonsdale Grammar School, and a firm and kind friend of Mr. Just during nearly a quarter of a century. It was the practice at this school, at the beginning of every half-year, for the pupils to repeat the Latin grammar, in such portions daily as they were able, till they had gone through the whole book. On one of these occasions young Just commenced, and continued his unflagging way so long that (after having gone through more than one-half of the grammar) he utterly tired out the patience of the master, who at length, suspecting that the boy meant to repeat the whole grammar at once, stopped him, quietly remarking that he had said enough for one lesson, and that he might repeat the remainder on the morrow!

When only about twenty years of age, Mr. Just became classical assistant to Mr. Dobson, and remained two or three years in that capacity, having during this time large opportunities of pursuing his own favourite studies. Whilst at this school, both as scholar and teacher, he manifested a strong attachment to natural history and botany; aud even as a boy, his indefatigable perseverance in everything he undertook, was a striking trait in his character. His readiness to help other lads with their lessons, and his serious demeanour and manly deportment, made him universally beloved and respected among his schoolmates. He was also pre-eminently distinguished by a love of truth and a very strong religious feeling; and these qualities were manifested in every action, so as to raise him greatly above the level of his youthful companions. In connection with his pursuit of natural history, he used to relate some amusing anecdotes (unconsciously illustrating his own kindliness of nature) of his obtaining birds and small animals, when a boy, and keeping them some time, with a view of testing the effects produced on wild creatures, by domestication and kind treatment. While assistant to Mr. Dobson, he used to rise in the summer months at four

o'clock, to pursue his favourite study of botany, not from books, but from nature. So thoroughly had he botanised the district, that there was not a habitat of any plant at all rare, within many miles of Kirkby Lonsdale, with which he was not well acquainted. He examined and named every plant himself, and in after years, whenever teaching botany, he made his pupils do this; urging that unless they acquired this habit, instead of trusting to others, or to books or engravings, they would never make sound botanists. As a young man, he was very fond of athletic and field sports; was a stalwart wrestler, an excellent shot, and a most skilful and successful angler. While yet a very young man, circumstances, to which it is unnecessary to allude, closed his connection with the grammar school; and he remained some years in Kirkby Lonsdale as a private teacher, dividing his time between his pupils and his studies, which were already multifarious. He was a very early riser, and thus secured many hours of uninterrupted reading, before his daily professional labours commenced.

Such was the smooth and even tenour of his life till about the year 1831, when the friend already referred to, who had, from reading with him and rambling with him, become greatly attached to him,—removing from Kirkby Lonsdale to the neighbourhood of Bury, and regarding that place as a wider sphere for his friend's talents and exertions than the remote and quiet little town where he was then resident,—induced Mr. Just to settle at Bury, where he received private pupils, and continued his own literary and scientific studies and pursuits with that avidity and perseverance which were amongst his most striking characteristics. He was thus occupied for about twelve months, when the Second Mastership of the Bury Grammar School becoming vacant, he was induced by friends to offer himself as a candidate, and was unanimously elected, in the year 1832; and this situation he filled with credit and honour during the remainder of his life.

His vacations were usually spent in pedestrian excursions, in which his love of nature, his taste for agricultural avocations, his eager pursuit of botany, and his keen zest for antiquarian researches, had full scope of enjoyment. In the midsummer vacation of 1834, he and the friend already referred to, made a pedestrian tour to the Highlands of Scotland, staying a few days at Fort William, on the Caledonian Canal. This being a convenient starting-point from which to ascend Ben Nevis, it was agreed that the friends should make a nocturnal ascent, so as to witness the sublime spectacle of sunrise from the summit. They left the hotel about seven o'clock in the evening, reached the top in time, greatly enjoyed the prospect, and got back to their hotel between six and seven o'clock on the following morning. Here they found another party preparing to make the ascent, and Mr. Just was so delighted with what he had already seen, and so ready to be useful as guide to the strangers, that before nine o'clock the same morning, after a short rest of little more than two hours, he was again *en route* for the mountain, actually accomplished the toilsome ascent a second time, and once more reached the hotel between five and six o'clock in the afternoon, apparently not more than comfortably tired by the extraordinary physical exertions of the twenty-four hours! It is right to add, however, that Mr. Just, on subsequently describing to a friend his two ascents of Ben Nevis, said that on coming down the second time, he walked as it were mechanically, and even seemed to himself to sleep whilst walking. This anecdote may convey a fair impression of the great muscular strength and power of endurance which he possessed, doubtless at times overtasked by that persevering energy which excited him to overcome every difficulty, and to fulfil whatever he undertook to do, however arduous the labour it involved.

Mr. Just could not long remain unknown, in his new position at Bury, and his literary and scientific acquirements soon

brought him into intimate and honourable connection with several of the literary and scientific societies and institutions of Manchester. He was appointed Lecturer on Botany at the Pine-street, now the Royal Manchester School of Medicine and Surgery, in September, 1833, as successor to Mr. William Thompson; and he delivered his first course of lectures there (always a summer one) in the summer of 1834. His course, which usually comprised from forty-five to fifty lectures, was regularly delivered by him yearly, till the summer of this year, when his health had become so seriously impaired, that he was unable to give a single lecture of the course for which he had been as usual announced. For the last few years of the eighteen,—during which period he was quite remarkable for the punctuality and regularity with which he fulfilled this engagement,—Dr. Hardy was associated with him in the course, his department being the descriptive; while Mr. Just developed the structural and more purely physiological branch of the science. Here his indefatigable exertions and habit of early rising, were taxed for contributions that might aid his botanical demonstrations; he would rise with the sun, traverse miles to collect the specimens he required for his lecture of that day, and return home in time to receive a private class of pupils at his own residence at the still early hour of seven in the morning. In his class he was never content that the students should accept his *dictum* on any matter capable of proof, and he therefore made it a rule invariably to demonstrate what he advanced. To the students he was ever accessible, and not merely willing, but ready and desirous, to give further explanations as to any points that might not have been fully understood during the lecture. Those who have been connected with Mr. Just in this institution, both as students and colleagues, speak of his lectures and teaching with gratitude and pleasure, and of his performance of his duties as a professor as most exemplary, and ever distinguished by zeal for the interests of the school, an earnest

desire to promote the advantage of the student, and the most cordial good feeling, friendship, and confidence towards his colleagues. At the annual distribution of prizes to the students, in November last, the founder of the school bore the fullest testimony to the merits, rare mental acquirements, and high moral character, of his deceased associate. To his connection with this institution Mr. Just looked back with much pride and pleasure; and as life ebbed away, he gave a characteristic recognition of his unfailing interest in that school where for eighteen years he had been so able, indefatigable, and successful a teacher, by bequeathing to it his valuable collection of dried botanical specimens—one of the best and most extensive in the country.

It was on the 22nd January, 1839, that Mr. Just was elected a corresponding Member of the Literary and Philosophical Society of Manchester, and he soon began to demonstrate that he was worthy of this position. In April of the same year he read his first paper to this Society; whose printed Transactions now include seven of his Essays,—three on Agricultural Science; two on Philology; and two on Roman Roads; besides two others on philological and archæological questions, not printed. These will be noticed under their respective subjects; but the fact of nine papers, bearing on four distinct branches of knowledge, and all contributed in thirteen sessions of this Society, will, to some extent, justify its desire to have a brief memorial of their deceased member, permanently recorded in their published Transactions.

In October, 1848, the Lecture Committee of the Royal Manchester Institution recommended that an Honorary Professorship of Botany should be instituted therein, and that it should be offered to Mr. Just; and the Council having unanimously confirmed the appointment, it was tendered to Mr. Just, who, in acknowledging the honour and accepting the office, expressed his earnest desire to discharge whatever duties might consequently devolve upon him, to the full

amount of his ability. And well did he redeem this pledge. In September, 1849, in his character of honorary professor, he delivered gratuitously a course of three evening lectures on Botany, at the Institution. In May and June, 1850, he delivered a more extended course of six afternoon lectures on Botany, and its various systems of classification. He delivered another afternoon course of six lectures in April and May, 1851, on the various organs of Plants. The syllabus of another course of six evening lectures, to be delivered in the May of the present year, shows another interesting grouping of subjects,—being notices of some of the great families of Plants.

But, alas! when the period came, the teacher was utterly unable to fulfil his engagement,—his days were already numbered and rapidly drawing to a close. He writes, on the 11th of that same month (May),—"I have been an invalid upwards of nine weeks, and can scarcely walk; whether I shall get out again I consider very uncertain." And again, on the 15th, having been urged to avoid such an excess of work as would wear out the strongest man, he writes—"I have been three weeks at home, and am no better. I can walk and that is all. It may be true that I am 'killing' myself with my labours. Mr. Goodlad [his medical attendant] urges most strenuously the necessity of giving up some portion of my labours. Of course, if required, I must do so. I must draw into a cottage and content myself with a little. The main consideration at present is getting out again." On the 27th, from Guy Hill, Tatham, near Lancaster,—"I have been here nearly a fortnight. Mr. Goodlad sent me hither to be out of the way; and whether I shall ever get into the way again is very uncertain. I am worth nothing, because I do nothing. I am in the midst of antiquities, and long to be on my legs; but I cannot walk more than a mile."

Returning to his connection with the Royal Manchester Institution, it should be stated that it was through his

medium, and probably on his recommendation, that the Institution received as a present from the family of the late John Roby, Esq., of Rochdale, in August, 1851, a collection of botanical diagrams, illustrating the classification and arrangement of plants, designed and executed by Mr. Roby and his son. At the monthly meeting of the Council, on the 3rd November last, a resolution was unanimously passed recording their deep regret for the loss which the Institution had sustained by the death of its late eminent Honorary Professor of Botany, Mr. Just, "whose profound knowledge of vegetable physiology peculiarly fitted him for the appointment;" and a copy of the resolution was forwarded to his widow.

Having noticed his botanical connection with two of our local public institutions, it may here be added, that his powers of discrimination, and of remembering the distinguishing marks and properties of plants, were most remarkable. On gathering any plant, even a moss or lichen, which he had ever before examined, even in years long past, he would, without any reference to books, at once name the plant; and if his correctness were doubted, he would then point out its distinguishing marks, and show wherein it differed from other similar plants. He was quite delighted whenever he was fortunate enough to discover the habitat of a scarce plant, and greatly disappointed and annoyed if by any means it became eradicated. He discovered a habitat of the Ladies' Slipper *(Cypripedium Calceolus)*, at Arncliffe, in Yorkshire; but, unfortunately, on its becoming known, the plant was soon extirpated by gardeners from the vicinity of Manchester. Many years afterwards he pointed out the place to a friend, expatiating on the delight he had experienced on discovering this *cypripedium*, and expressing his strong regret that so rare a plant should have been eradicated for the purpose of sale. The friend who was with him when he found this plant (he thinks in the year 1835) thus describes the discovery:—"It was on a fine morning in July. We were quartered at Arncliffe, and before

breakfast had rambled into a *scroggy* limestone wood, for the express purpose of looking for the *Ladies' Slipper*, which, we were told, had been found there within the last ten years. Imagine the eagerness with which every nook, both likely and unlikely, was searched. We had separated from each other, a distance of perhaps twenty yards, when I was attracted by a joyous scream; at the same time, I saw my friend's hat high whirling in the air; and, with a school-boy's delight, he thrice shouted—'Eureka, Eureka, Eureka!!!' And sure enough there was the envied prize,—two plants in beautiful bloom, and five smaller seedlings. We each brought away one of the blooming plants; and I am afraid the news of our success proved fatal at length to the seedlings."

The same botanical friend has recorded of Mr. Just that—"As a vegetable physiologist, he might be placed in the first rank, although he never extended his acquaintance with plants beyond those that are indigenous to Britain; but in every department of British Botany he was thoroughly versed. The plants of our own country afforded him a field ample enough to study the *laws* of the vegetable kingdom, which were the great objects of his research, and in which he made many interesting discoveries. To know the names of a great number of plants, or to have dried specimens pictorially laid down upon paper, was not what he termed Botany. A precept of his, which deserves to be remembered, and which he once repeated to me, when I remarked that I knew a particular plant from a certain resemblance that it bore to some other, was—'If you wish to become a botanist, you must learn to distinguish plants by their *differences*, and not by their *likenesses*;'—a piece of advice I have found useful on many occasions since. He was especially fond of Cryptogamic Botany, as exhibiting the wonders of Creative Wisdom, displayed in these pigmies of vegetation; and many a new species was discovered by him, before it made its appearance in any English work, or was considered as a British plant."

His pursuit of botany and the associations of his boyish years on his father's farm, must naturally have combined to turn Mr. Just's attention both to the science and the practice of Agriculture; and (as in all his other studies), he qualified himself to teach the philosophy of their operations to farmers themselves; to point out their faults and mistakes; and to offer them many valuable practical suggestions for their guidance, in various farming operations. He was well acquainted with chemistry, and paid considerable attention to its application to the analysis of soils and manures, and other purposes connected with the science of agriculture. As a geologist, he was also well informed, and made his knowledge of this science contribute its quota to his investigation of the philosophy of vegetable culture. Of the results of his observation, inquiries, and experiments in this branch of science, a few only can be indicated here. Three of his agricultural essays enrich the Transactions of the Literary and Philosophical Society of Manchester.

On the 18th November, 1845, Mr. Just read before this Society, a long and able paper "On the Philosophy of Farming," printed in its Transactions, (New Series, vol. vii., p. 574.)

On the 10th August, 1847, Mr. Just read before this Society another valuable paper "On the Maturation of Grain and Farming Produce, so as to be most beneficial to the Cultivator;" and it is printed in the Transactions, (New Series, vol. viii., p. 297.)

On the 9th May, 1848, Mr. Just read an admirable practical paper "On Faults in Farming,"—chiefly as observed by him in the neighbourhood of Bury,—in the waste, the collection, and the application of manures, solid and liquid,—concluding with useful hints on the waste of manures in large towns. This is the last printed paper of your corresponding member, being included in the ninth volume of the Transactions, (p. 93.)

On the 27th September, 1850, Mr. Just delivered before the Bury Agricultural Society, "A Lecture on the value and properties of Lime, for Agricultural Purposes," with analyses of several specimens; and so highly did that Society estimate the great amount of valuable information contained in this lecture, that it was printed in a separate form, as a pamphlet, (pp. 16.)

Connected with this investigation, Mr. Just analysed more than thirty varieties of lime, obtained in the neighbourhood of Clitheroe, for a gentleman resident there; and here, as in many other ways, he made his scientific knowledge directly applicable to the promotion of practical improvements in the industrial operations of ordinary life.

Every busy man who looks forward at all, delights to think of a time when he may have leisure to pursue his favourite studies; and Mr. Just often expressed a hope to his intimate friends, that at some future time, after his child's education had been completed, he should be able to give up his more arduous duties, and retire to some quiet spot in his native county, where he could complete the great philological work on which he was engaged, and enjoy botany and agriculture as healthful recreations.

As his knowledge of chemistry, geology, botany, and even mathematics, were all brought to bear on his researches into agricultural science,—so Mr. Just made his investigations in philology, and his archæological pursuits, give to each other mutual aid and light. His knowledge of the Latin and Greek languages and literatures, was the ready handmaiden in numismatical inquiries, or in the investigation of the traces which the Romans have left behind them of their rule, in the North of England;—while his extensive familiarity with the Teutonic tribe of languages, enabled him to comprehend much of the life and manners of those whom he was wont to call "our Saxon fore-elders." His long study of the ancient tongues of Scandinavia, and his thorough acquaintance with

the theory and linguistic rule of that profound philologist, Rask, coupled with his intimate familiarity from childhood with the peculiar dialect of Westmorland, qualified him to point out many unsuspected affinities between the proper names of men and places, still existing in the North of England, and the old Norse and Danish tongues,—enabled him to trace many archaisms to their Scandinavian origin, and greatly assisted him in the decyphering and translation of old Runic inscriptions. From this close interweaving of kindred sciences and branches of knowledge, it is by no means easy to note separately his acquirements in each. But first as to philology, it may be observed that while at the Kirkby Lonsdale Grammar School, he became a good Latin, Greek, and Hebrew scholar; after taking up his residence in Bury he acquired a sufficient knowledge of French, German, Italian and Spanish, Swedish and Danish, to read any author in those languages; and his strong desire to trace to its various sources his own vernacular tongue, led him to acquire a thorough knowledge of the Anglo-Saxon and other Teutonic languages; of the old Gothic and Scandinavian tongues, no less than of their modern forms; and even to extend his researches into the structure of the ancient British and other Celtic languages and dialects.

The gentleman of whom he took lessons in French, was struck with his great power of acquiring and retaining the more difficult parts of the language, as the idioms, the irregular verbs, &c. So extensive was his knowledge of various languages, that being once asked how many he knew, he enumerated upwards of twenty of which he had some knowledge, seventeen of which he knew structurally. But, though of these he could not only read but write many, he was unable to speak any but his native English, and those who knew him will remember that he retained much of the pronunciation of his native county,—the broad Doric of his Anglo-Danish birth-place.

In order to keep up an intimate acquaintance with the various languages he had acquired, his custom was to read them in rotation, devoting a certain time (it is believed a week) to each; and he said that by thus taking them in succession, he managed to retain all, and found his mind relieved by the change from one to another. On Sunday he always read the Hebrew Bible.

These philological studies, as might be expected, were eagerly pursued, with all the avidity and perseverance of his energetic character and ardent temperament. And, widely different from those churlish natures by whose selfish studies the world never profits, Mr. Just's rapidly extending knowledge of languages, soon began to bear fruit.

On the 4th April, 1843, he read a paper before this Society entitled "A brief history of certain Anglo-Saxon roots, nearly obsolete in the English language," which was printed in the Transactions, (New Series, vol. vii., p. 391.)

On the 12th November, 1844, Mr. Just read to the Society his "Dissertation on Anglo-Saxon Patronymics," printed in their Transactions, (vol. vii., p. 440.)

On the 16th April, 1850, he read before this Society a paper (not published) "On the Self-acquirement of languages," which was curious and interesting as an indication of the means for such acquisition which had been so singularly successful in his own study.

His latest philological essay was contributed to a local society of antiquaries, calling themselves "The Rosicrucians," and was written late in August, and read at their meeting on the 6th September, 1852. It consisted chiefly of brief expositions of the origin and derivations of local names, especially those common within the hundred of Salford.

But his great labours in philology were connected with the compilation of a Dictionary or Lexicon of English words, and their derivations, with similar words, of similar meaning, in cognate and kindred languages. To this end he was for many

years engaged, during the little leisure he possessed, in making a collection of words, which he was tracing through different languages and dialects to one common root. Of late years, as the Herculean character of this labour pressed upon his mind, together with the growing consciousness that the springs of life were beginning to fail, he used to say that if he did not live long enough to complete his work, at all events he should leave something by which to be remembered after he was gone; and that if he should not live to publish it himself, he should leave it to some society, on condition that they gave it publication. I have had an opportunity of examining this "Dictionary," which, in four quarto volumes, contains several thousand words. First is given the English word; next its immediate derivation, and from what language; third, its meaning; and lastly the words of like significance from other languages, all traceable to the same root. He appears purposely to have omitted from his plan all words derived from the Latin or Greek, or from the British; and his Lexicon comprises mainly the words having their origin in the Teutonic, Scandinavian, and Gothic tongues. At an earlier period, he had begun in the same volumes to note down Hebrew words having affinity for English ones. In this work he was engaged even till within a few weeks of his decease,—as long, indeed, as he could hold the pen; and its last thirty-two pages contain some two hundred words, the derivations of which, and their roots, must be traced, if at all, by some other hand.

Subordinate and auxiliary to this, he was engaged in another philological compilation, which occupies two quarto volumes in MS., and which he has himself entitled "A Glossary of the Westmorland Dialect, as spoken in the neighbourhood of Kendal." This is alphabetically arranged, and under each archaic word is given a short illustrative phrase or sentence in the Westmorland dialect; and to this is occasionally appended the derivation of the word from some Scandinavian or Anglo-Saxon root. So long ago as August, 1843, he writes to a

friend—"Tho' idle while in the 'North countree,' I picked up many provincial words; having constantly before me the purpose of severing the Northern dialects into their true original parts; provided I live long enough to be able to accomplish my task *just* as I wish, and *just* as *Just* ought. The Danes have had long possession of the Vale of Lune,—using the stronghold of Lancaster as their head-quarters, and leaving behind them six or seven 'haughs' or artificial mounds of their peculiar character. This accounts for the superabundance of pure Danish words in the district. Want of information on this head, has led authors into errors in their conjectures respecting the people who constructed the *tumuli*,—some saying they are British, others Roman."

On this subject, he briefly enunciated his views in a paper entitled "The Danes in Lancashire," read before the Historic Society of Lancashire and Cheshire, at Liverpool, on the 6th May, 1852,—his last contribution to the published Papers of that Society, and which is posthumously printed in its recently issued Vol. iv., p. 121. From July, 1843, to his decease, he was a member of the Chetham Society; but did not contribute anything beyond an interesting note or two, to any of its printed volumes.

Akin to his philological pursuits, on the one hand, and to archæology on the other, was his decyphering and translation of various Runic inscriptions in England and in the Isle of Man. His first essay in this direction was upon a number of plaster casts, taken by Mr. William Bally in the summer of 1839, of all the Runic inscriptions on crosses in the Isle of Man. Various attempts had been made to decypher some of these; but without success, owing in some cases to ignorance of the Runic characters, and in others to want of acquaintance with the language in which the inscriptions were graven.

That which Gough's *Camden*, Mr. Beauford, Sir John Prestwich, and Professor Torkelin successively failed to elucidate, yielded to the sagacity and perseverance of Mr. Just,

who first saw the casts in the autumn of 1842, and sent copies of the inscriptions, with translations, in January, 1843, to Joseph Train, Esq., F.S.A. of Scotland, which are published in that gentleman's "*History of the Isle of Man*," (vol. ii., pp. 32—36,) in juxtaposition with the previous attempts.

On the death of the late Dr. Edward Holme, a stone cross was found in a box in his cellar, which had formerly stood in the churchyard of St. Mary, Lancaster. In August, 1848, this Runic cross was presented by Dr. Holme's residuary legatees, the Council of University College, London, to the Manchester Natural History Society; and a few plaster casts having been taken of the inscription, the cross was placed in a glass case, in that Society's Museum, Peter-street. This inscription had been repeatedly engraved, and had long been the subject of examination by antiquaries. The late Dr. Whitaker, the historian of Whalley, offered one attempt at decyphering and translation, and held it to be Danish; Baines's *Lancashire* gave another, terming it Runo-Danish. In 1836, the late Professor Finn Magnusen, of Copenhagen, having received a cast of it from the late Dr. Hibbert-Ware, offered a fourth interpretation, regarding it as Scandinavian. A fifth was given in 1847, by Mr. Kemble, the learned translator of Beowulf, who pronounced it Anglo-Saxon. In August or September, 1848, Mr. Just received a cast of this inscription, and another was transmitted to the learned Dr. Grimm, whose interpretation has not been given to the world. In January, 1849, Mr. Just published his decyphering and translation, agreeing with Mr. Kemble that the language of the inscription is Anglo-Saxon; but differing with that learned Saxon scholar as to the characters themselves.

On the 12th April, 1849, Mr. Just read before the Lancashire and Cheshire Historic Society, and on the 1st May, before the Literary and Philosophical Society of Manchester, a paper "On the Reading of the Lancaster Runic Inscription,"

which is printed in the Transactions of the former Society, (vol. i., p. 121,) accompanied by a wood engraving of the cross and another of the inscription,—and giving the various readings already referred to.

Having taken some part in these investigations, it is to me a matter of regret, that this Runic inscription should still have appended to it, in the Museum, two erroneous translations, when, in point of fact, that of Mr. Just, made nearly four years ago, has the highest claims to accuracy.

The latest labour of this nature undertaken by him, was during his last illness, in September, 1852. A friend, having seen in the *Illustrated London News* of August 28th, 1852, a wood engraving of an ancient slab found in St. Paul's Churchyard, London, with a fac-simile of two fragmentary lines of Runes upon it,—transmitted to Mr. Just his decyphering of the characters, which was promptly verified and returned with a translation of the Runes, which, in the form of a joint letter to the Editor of the above periodical, was published in the *Manchester Guardian* of September 4th, 1852. This was but six weeks before his decease, and is believed to be his last contribution to archæology, or, indeed, to any branch of science.

The circumstance that both at Natland, his birth-place, and at Bury, where he resided during the last twenty years of his life, Roman roads and remains exist, seems to have induced him, with his characteristic energy, to devote himself to the careful examination and tracing of the great military roads traversing Lancashire from north to south, and from west to east. The information which he thus collected by personal inquiry and examination of the district, led to his temporary connection with the Officers of the Ordnance, while they were engaged in the survey of Lancashire. This gave him an opportunity of verifying the conclusions he had formed; and these conclusions are now transmitted to posterity in a permanent, official, and authoritative form; the lines of

road as demonstrated by him having been laid down on the Ordnance Maps. It was in connection with this subject that Mr. Just first contributed to the Transactions of this Society.

On the 2nd April, 1839, Mr. Just, recently elected corresponding member of the Literary and Philosophical Society of Manchester, read before it "An Essay on the Roman Road in the vicinity of Bury, Lancashire," which is printed in its Transactions, (New Series, vol. vi., p. 409.) He accompanied this essay with a sketch of the line and remains, not only as an illustration of his paper, but valuable as a guide for any future investigator.

On the 22nd March, 1842, Mr. Just read before the Society a paper "On the Roman Military Road between Manchester and Ribchester," which was printed in their Transactions, (New Series, vol. vii., p. 1,) illustrated by an engraved map of the line and remains.

On the 1st February, 1849, he read before the Historic Society of Lancashire and Cheshire, (of which he was a member from its formation in June, 1848, till his death,) the first part of a paper "On the Roman Roads in Lancashire, with a particular account of the Tenth Iter of Antoninus."

On the 17th November, 1850, he read the second part of his paper before the same Society, which treated of the Seventh Iter of Richard of Cirencester,—in other words, the military road traversing Lancashire from west to east,—from the Portus Sistuntiorum (on the Wyre?) to York.

The British Archæological Association having fixed its seventh annual congress to be held in Manchester and Lancaster, in August, 1850, and its President of the year having offered a donation to defray the cost of excavations at Ribchester, for Roman remains, provided Mr. Just would undertake the superintendence of such operations, he made several visits to Ribchester for this purpose; and the results were exhibited to the Association on their visit to Ribchester;

the foundation of the outer wall being laid bare; a quantity of Roman pottery found, chiefly fragments of Samian ware, many marked with the potter's name; an ampulla, &c.; five Roman coins, three of silver, (Vespasian, Titus, and Vitellius,) and two of copper, &c. A paper "on Roman Ribchester," the joint production of Mr. Just and a friend, was read before the congress at Manchester, on the 22nd August, 1850, and is published in the Journal of the Association, (vol. vi., p. 229,) with various illustrations of Roman altars and inscribed stones found at Ribchester.

The catalogue of Mr. Just's varied learning and acquirements is not yet exhausted. A friend writes of him that "he was not less diligent or less successful in scientific pursuits, than in the acquirement of languages. He was well versed in mathematics, and in natural philosophy there was scarcely any branch of science that he had not thoroughly studied both practically and theoretically. * * * If his circumstances or the help of his friends had given him [in youth] the means of pursuing those studies, for which he had so great a taste, and accompanied with the advantages in due course of a university education, he would not unlikely have gone on in the same career of distinction with some of those pains-taking scholars of the North, who, like a Sedgwick or a Whewell, have gained for themselves the highest distinction for their contributions both to literature and science." In early life it was his intention to have entered the Church as a profession; but circumstances, greatly to his disappointment, prevented his carrying this strong desire into effect.

Although during the whole of his residence at Bury, he was so unremittingly engaged in the work of teaching, both at school and at home, he was a regular teacher at St. John's Sunday School, twice a-day. He also occasionally lectured at the Church Institute at Bury, and to the Bury Mechanics' Institution. In 1836 or 1837, he was one of the promoters of a Literary and Philosophical Society in Bury. It only

existed a short time, but during its continuance he was one of its ablest contributors. He was also a member of a society for giving and receiving instruction in science and literature, and generally answered his full quota of the questions proposed, although some of them required great research. Amongst his multifarious pursuits, he found time to record in a book kept for that purpose, a series of daily meteorological observations, taken at his residence at Chesham Green, near Bury, from February, 1838, to February, 1851; and in looking over this volume, extending over thirteen years' daily observations of both barometer and thermometer, I have found no blanks unaccompanied by an explanatory note to the effect that he was from home at the time.

Mr. Just was from boyhood a very keen and successful angler; and a friend states that many an experienced fisher on the Lune and the Kent, would suspend his sport, in order to watch Mr. Just's more artistic and successful casts of the line. For many years he made an annual fishing excursion for a week at Easter, and generally for a couple of days, at the annual Bury fairs in March and September, when he could get released from the Grammar School. He always looked forward to these excursions with great delight, because they served to recruit his health, as well as to afford him the enjoyment of his favourite sport. He was generally the first on the stream in the morning; the last to leave it at night. He brought his energy and his powers of observation to bear even on his amusements, and had formed the opinion that colour and size were the only essentials in flies. He thought that the flies fell upon the water in so many planes relatively to the eye of the fish, that it was impossible for the fish to distinguish their form. He therefore regarded it as waste of time to make *winged* flies, and never used any but hackle flies, and those generally small. He was so much occupied at home, that he usually had to make his flies before going out to fish in a morning. On these excursions he examined

all the antiquities and curiosities in the neighbourhood, and also collected plants, more particularly of late years, the Cryptogamiæ, which he examined at night, or (if any of the party had no taste for such pursuits) in his bedroom in the morning. Such was his ambition to excel in anything he undertook, that he has seemed as much annoyed by any one doubting his skill as an angler, as if his capabilities as a botanical lecturer, or a philologist, had been called in question. The same conscientiousness which was conspicuous in the graver transactions of life, was manifested in the midst of his amusements. His strong love of truth was ever apparent, and though passionately fond of angling, whatever others might do, he always attended Church on the morning of Good Friday.

In all that has been enumerated of Mr. Just's favourite pursuits and remarkable acquirements, nothing more has been done than to give a feeble and imperfect portraiture of the immense amount of actual work accomplished by him in those brief snatches and intervals, those small "strays and waifs of time," which so many allow to slide away, as too short and insignificant to attempt to render available to any important or useful end. To him alone, nine-tenths of whose time is mortgaged to the duties and business of life, can leisure have a peculiar value and a charm, that even wealth without it cannot compensate. Besides his daily duties at the Bury Grammar School, which, (distant nearly a mile and a half from his residence,) may be said to have consumed his whole day, he gave private lessons at his own house, both morning and evening; teaching the mathematics, classics, modern languages, &c., preparing young men for college, reading with others who wished to keep up their scholastic acquirements,—and thus even the hours before the morning and after the evening meal, still found him labouring at the drudgery of tuition. In the summer months he had a class at his own residence at seven o'clock in the morning,

and again evening classes extending till nine, and often even until ten o'clock. His whole ordinary day thus absorbed, the wonder is how and when he snatched the time for acquiring his varied knowledge, or even for communicating some of its stores to others in the shape of papers and essays. So early as March, 1840, he wrote of stealing an hour from his bed to examine some Runes; and at various times he expressed to his friends his regret at being unable to correspond with them more fully, as every letter he wrote was penned during the time which should have been devoted to repose.

In October, 1834, he writes—"Now that my lectures are ended for the present, and I was anticipating leisure and repose, I find myself almost as busy as ever; so that I seem fated to constant and uninterrupted labour. I, however, console myself by being thankful to a good God for fitting my shoulders to the burden; so that, like the ass in the fable, I trudge contentedly on with my panniers, indifferent who are my masters."

There is no need of multiplying extracts through a series of years to show that each succeeding season seemed to accumulate new labours and additional tasks,—even his Saturdays, the only day of the six on which he was relieved from school duties, being at length engrossed by an engagement as actuary at the Bury Savings' Bank. If it be asked why he should have taken this immense amount of labour upon him, the answer, resolving itself into the old "res angustæ domi," may be given in his own words, September, 1840,—"I have brought cares upon me such as you feel and know to be all-absorbing,—those of husband and father,—and it is in these relations that I exert myself for others in such a way as nothing on earth could induce me to do for myself." To a friend who frequently urged him to give up some of his engagements on the score of ill health, he always said he would do so, as soon as his child was educated, but that until then he *must* work, and he thought his constitution was strong enough to bear it.

It will naturally suggest itself to the minds of all who have watched the physical consequences of a mind o'erwrought,—that these whelming and unremitting labours must, sooner or later, tell on even the hardiest frame and strongest constitution. And such was the inevitable consequence in this case. So long back as July, 1843, Mr. Just writes,—"I feel like a breaking-down horse, a want of putting-out to grass for a short period, to repair my exhausted energies." After a month's holiday, spent in the North, he writes,—"Being returned from 'grass' to 'gear,' with the gain of 7lb. of animal matter, as a store to consume during the current half-year in mental pursuits, I have straightened up arrears." In this way half-year after half-year passed over, making every vacation necessary to repair the wear and tear undergone. Close confinement, a hard-worked if not an overwrought brain, and a want of sufficient bodily exercise, had the usual result of inducing a sluggish state of the liver, with other concomitant derangements of the digestive functions. For the last two or three years he was subject to attacks of faintness, especially when, during his vacation excursions, he over-exerted himself, and he was sometimes obliged to seat himself on the river's brink till the attack passed off. Usually he was most liable to these attacks for the first two or three days of the excursion, and at times they unhinged him, and he became very nervous. He generally attributed them to indigestion, and at times he said he was sure he had disease of the heart. He became better after taking considerable exercise. Last Easter his fishing excursion was to Whitewell, and there he did not recover after a few days as usual; he could not retain his food, and apparently derived no real benefit from this excursion; and he observed, that it was the first time he had ever come home with his strength unrecruited. Still he fished as keenly as ever; and he manifested his love of science to the last. A friend calling to see him on the 21st September, on his

return from an excursion in Devonshire, Mr. Just, whose recovery was then known to be hopeless, took great interest in the plants his friend had collected, and made various inquiries about the geological formation of the county. Long after he was forbidden to read, he rejoiced in being allowed to use his pen, in extracts and transcription, and he employed it as long as he could wield it, in registering philological facts for the information of others.

To prolong the narrative of his latest hours is at once painful and unnecessary: suffice it to say, that after calmly arranging his affairs, even to the naming of those friends whom he wished to be invited to attend his remains to the grave, he expired on the morning of Thursday, the 14th October, 1852, in the 55th year of his age.

From the preceding April he had been unable to discharge any public duty, and during the greater part of this time he was confined to his room. During his last illness he manifested an exemplary patience and unrepining submission, with earnest faith and trust in God. His conduct and conversation impressed his friends with the conviction of his strong religious feeling, and serene and unaffected piety. He ever recognised the union between science and religion, and often expressed his surprise that any one who had pursued truth in science, should fail to recognise its holy presence in religion. He was warmly attached to the Established Church, and a regular attendant on its ordinances, and he took much interest in the welfare of the young men who formed his class at St. John's Sunday School. His remains were interred in St. Paul's Churchyard, Bury, on Wednesday the 20th October;—being borne to the grave by four of the teachers of St. John's Sunday School. The funeral was attended by many of his friends from Bury, Manchester, and other places, and also by the Masters and Scholars of the Bury Grammar School, who met the procession before it reached the church, to show their respect for his memory. He has left a widow and one daughter, now fifteen years of age.

So much has the length of this memoir exceeded my intentions, that only a few extracts from his private correspondence can be given here; and they are selected as revealing some of the phases of his mind and character. Writing to a poetic correspondent, he asks—

"Is poetry a sound of words?
Or is't a happy thought?
There's poetry in many a soul
That rhymed not what it wrought."

"Real poetry (he observes) flashes through the mind, like lightning through the heavens;—it comes only at intervals, unsought for, unpremeditated. Like the rod of Moses, it only works miracles when inspiration is upon it. You may strike the rock at other moments, but there is then either no flow, or the few drops which follow are but muddy water." * * "I still feel and enjoy poetry—the poetry of the mind and of fine feeling—aspirations devout, kindled by nature, burning with the fragrance of her incense, and ascending, like the smoke of the altar, towards heaven, waiting for admittance there."

In reply to a correspondent who had spoken of his genius, he denied the possession of that high attribute, adding—"If knowledge has thrown some rays of her light upon me, so that daylight shines around me upon subjects which are in midnight darkness to many others, it is labour which has struck out the treasure from a barren mind—like Moses striking out rivers of water from the flinty rock;—it is diligence and perseverance that have surmounted all. A man knows nothing of himself till he tries himself. Want of exertion,—that idleness which springs from the cowardice of our nature,—ruins all."

Writing in April, 1834, to a friend, he says—"You rally me upon the gaiety of the life I am leading. It is far from being congenial with my feelings, and instead of adding to, subtracts very materially from, my happiness. I often envy

the days gone past, when alone, in woods and wilds, I took my solitary rambles, unnoticed by any one, and conversing with God and his wonderful works, in nature alone. Such a course gives an elevation to the mind and a tranquility to the conscience, which not all the flattery of the great and the approval of the wise in this world, can produce. Often have my friends, when I lived in retirement in Kirkby Lonsdale, scolded me for the apathy and indifference which I manifested towards my own welfare in the world, and my advancement in society; but, spite of all, I was then wise. The improvement of my own heart and mind was then the sole object of my ambition, and would it still were so! I would I had the chance of retiring into some sequestered vale, with the prospect of a pittance for life, just sufficient to keep me from the meanness of poverty, without the power or the temptation of becoming rich; that every night I might lay my head upon my pillow with the satisfaction of knowing that I was becoming wiser and better every day."

Again:—"We live not by time, but by thoughts; and a truth once felt,—it lives with us and becomes a part of our being."

One more extract:—"Happiness is within the reach of all. Affliction may impair our relish for one kind of happiness; but if we improve it, it sharpens our relish for another kind. Bad health may becloud one sense; but it throws brightness and daylight upon others. Whatever betide, happiness may be ours, if we be but resigned. Nay, give us all we desire,—make our wishes start up into realities, fast as we form them,—and instead of being happier, we shall be more miserable. We are all placed by Providence just in that situation which is, on earth, calculated to furnish us with most happiness. Whether we make it so, depends upon ourselves, and is one of our many responsibilities. * * Nature is my garden; and who or what man or woman, or destroying spirit, can spoil it? I may have no pet place wherein to

shelter my favourite flowers; but they are still as beautiful in my eyes,—wherever seen,—wherever they may blow. Give me a cot in the country, and quiet, and I desire no more. The fields around will furnish me with delight, as I visit the flowers which none knows or sees, but the industrious bees and myself."

In all his pursuits, he seemed ever to set before him the injunction of the Hebrew Preacher—"Whatsoever thy hand findeth to do, do it with thy *might*." Immense energy, indomitable perseverance, unrelaxing industry, a keen and omnivorous appetite for knowledge, and the active and economic use of every moment of disposable time,—these furnish the real solution to the problem of his extraordinary attainments and labours, during the small surplusage of a life spent in scholastic teaching. He was gifted with extraordinary powers both of arranging and classifying the knowledge thus acquired, and of retaining it in his memory ready for immediate use. But he evidently regarded his work as only half done, so long as it was limited to acquisition; for here again his practice was invariably in accordance with the apostolic precept,—"To *do good*, and to *communicate*, forget not." Hence his disinterested readiness to share the fruits of his erudition and his scientific acquirements, with all who sought his aid. His intellectual nature seemed delighted to gather honey everywhere; his moral nature to share the sweet product with all who could derive nutrition from it. He cared little for fame; much for opportunities of usefulness. In the simplicity and manliness of his nature, he could be equally the cheerful companion of youth, of manhood, or of age; and those who knew him most intimately, oft rejoiced in his sportive sallies, as well as listened with a reverence,—the more earnestly paid because never sought to be exacted,—to the lessons of wisdom which were freely and spontaneously uttered in his hours of friendly intercourse. No branch of study in his hands was barren; all acquisition was rapidly

assimilated, converted into the practical and the useful, and disinterestedly diffused with a cordial desire to serve his fellow-men.

In his social and domestic relations he was most exemplary; and whether in the domestic sphere, as son and brother, husband and father; or in the wider and constantly widening circle of friendship,—he has left a memory that must ever be cherished with the tenderest regard, as it will be revered with the involuntary respect which we cannot withhold from those, whose lives have been pure and constantly dedicated to the advancement of knowledge; to the intellectual and the moral improvement of others; and in these ways,—imperfectly it may be, but still faithfully, zealously, and piously,—to the honour and glory of God.

V.—*The Lancashire Geometers and their Writings.*

By T. T. Wilkinson, F.R.A.S., Burnley.

[*Read December 28th*, 1852.]

The extensive cultivation of the Ancient Geometry in Lancashire and the northern counties generally, is a fact which has forced itself upon the attention of several observers. From a very early period of our scientific history, Lancashire and the North have furnished their full quota of representatives to the councils of Mathematical inquiry; their hardy veterans have oftentimes led the way to brilliant and useful discoveries. Nor have these successful pioneers by any means been confined to that class of society where "luxury and learned ease" may be supposed to have lent their aid in accelerating the progress of human knowledge. If proof of the general assertion were required, we need only refer to the labours of the late Dr. Dalton and the *Memoirs of the Manchester Literary and Philosophical Society;* but with regard to geometry in particular, the pages of our mathematical periodicals will readily furnish more exquisite specimens of the geometry of the Greeks, mostly produced by Lancashire operatives, than could be found in many laboured treatises of those whose official stations have led them to cultivate the subject.

Mr. Harvey well remarked to the York Meeting of the British Association for the Advancement of Science, in 1831, that there had long "existed a devoted band of men in the North of England, resolutely bound to the pure and ancient forms of geometry, who in the midst of the tumults of steam-engines, cultivated it with unyielding ardour, preserving the

sacred fire under circumstances which would seem from their nature most calculated to extinguish it. In many modern publications, and occasionally in the Senate House Problems proposed to the candidates for honours at Cambridge, questions are to be met with derived from this humble but honourable source. The true cause of this remarkable phenomenon I have not been able clearly to trace.

"A taste for pure Geometry, something like that for Entomology among the weavers of Spitalfields, may have been transmitted from father to son; but *who* was the distinguished individual first to *create* it in the peculiar race of men here adverted to, seems not to be known. Surrounded with machinery, with the rich elements of Mechanics in their most attractive forms, we should have imagined that a taste for mechanical combinations would have exclusively prevailed; and that inquiries locked up in the deep, and to *them* unapproachable recesses of Plato, Pappus, Apollonius, and Euclid, would have met with but few cultivators. On the contrary, Porisms and Loci, Sections of Ratio and of Space, Inclinations and Tangencies—subjects confined among the Ancients to the very greatest minds—were here familiar to men whose condition in life was, to say the least, most unpropitious for the successful prosecution of such elevated and profound pursuits. The contrast also between the northern and southern parts of England, in this particular, was most remarkable. In the latter the torch of Geometry emitted but a feeble ray; while in the former it existed in its purest and most splendid form. The two great restorers of the ancient Geometry, Robert Simson and Matthew Stewart, it may be observed, lived in Scotland. Did their proximity encourage the growth of this spirit? Or, were their writings cultivated by some teacher of a village school, who communicated by a method which genius of a transcendental order knows so well how to employ, a taste for these sublime inquiries, so that at length they gradually worked their way to the anvil and the loom?"

The late Professor Davies directed attention to these circumstances in *Notes and Queries*, No. 31, and in No. 34 of the same work I have attempted to trace the "*Origin and Progress of the Study of Geometry in Lancashire*," so far as my means of information would then permit; nor am I without a hope that, in the paper alluded to, I have succeeded in assigning some of the true causes of this "remarkable phenomenon," and in furnishing correct answers to Mr. Harvey's interesting inquiries.

Mr. Halliwell's *Collection of Letters on the Progress of Science in England* sufficiently proves that the study of geometry was at a very low ebb in England previously to the commencement of the eighteenth century. Dr. John Dee, the celebrated author of the *Preliminary Discourse* to Billingsley's *Euclid*, was indeed Warden of the College at Manchester, (A.D. 1595,) but his residence here could effect little in favour of pure Geometry. His versatile talents, however, may have given an impulse to the study of Natural Philosophy and Astronomy, for, in A.D. 1633—1641, we find Horrocks and Crabtree, both natives of Lancashire, the former of Toxteth, near Liverpool, and the latter of Broughton, near Manchester, especially distinguished in Theoretical and Practical Astronomy. Their labours in these subjects have recently been described at considerable length by Mr. Grant, F.R.A.S., in his able *History of Physical Astronomy*, but it does not appear that they ever paid any special attention to the ancient geometrical analysis. Indeed, had such been the case, their early death (A.D. 1641) would have prevented the exertion of any considerable influence in its favour, for it necessarily requires a long and distinguished career for individuals to succeed in reviving a taste for the cultivation of a branch of science so long neglected.

Of Christopher Townley, of Townley, near Burnley, we know little except that he was the transcriber of the *Townley MSS.*, so well known to every antiquary. The friend of Edward Sherborne, the translator of Manilius's *Treatise on Astronomy*,

and intimately acquainted with Horrocks and Crabtree, his pursuits would probably be of the same nature as those of his illustrious friends; and although his nephew, Richard Townley, is known to have been an ardent cultivator of science, and to have resided principally at Townley, he, like the former, was probably more engaged with experimental physics and astronomy than with pure geometry. My copy of *Pappi Math. Coll. a Commandino*, (Venetiis, 1589,) however, contains his name and armorial bearings, and consequently must formerly have been in his possession. The probable inference therefore is, that he was not altogether ignorant of the contents of this valuable collection of the fragments of ancient geometrical research; and it may be mentioned to his honour that he was the *first* to discover what is usually known as "*Marriotte's Law*" for the expansion of gases, which Professor Oersted remarks, (*Phil. Magazine*, August, 1826,) he deduced from some experiments made by his friend Mr. Cavendish. Nor is his name altogether unconnected with geometrical inquiries, for he is well known as the reproposer of the "*Problem of Hipparchus*" relating to the determination of the point from which three objects, not in a straight line, may be seen under given angles, which was solved in all its cases by Mr. Collins, in the *Philosophical Transactions* for 1671.

Although the studies of the Lancashire Mathematicians up to this period did not tend to develope themselves very fully in any specific direction, yet it is evident that an interest in the cultivation of Geometry had gradually been created in different localities, and that the number of its admirers in Manchester and its vicinity was steadily increasing; so much so, indeed, that a Mathematical Society was established here in 1718, on principles very nearly similar to that in Spitalfields, London, which had been founded by Mr. Joseph Middleton the year before. Mr. James Crossley, of Manchester, the learned President of the Chetham Society, has given an interesting account, in *Notes and Queries*, No. 103, of the first two lectures delivered before the Manchester Society by "the late

ingenious mathematician, Mr. John Jackson," and "*he*, having discharged himself well becoming his parts and character in the reading of several extraordinary ones in Geometry," which were afterwards published, may justly be regarded as the *Father of the Lancashire School of Geometers*. At a later period, A.D. 1728—1763, the name of "John Hampson, of Leigh, in Lancashire," appears as a correspondent to the *Lady's Diary*, but since he mainly confined his speculations to the Diophantine Analysis, he cannot be considered to have caught the mantle of his predecessor.

The Manchester Society does not appear to have produced any very immediate effects, for although its existence would tend to nourish and preserve the incipient taste for Geometry thus produced by the discourses of Mr. Jackson, no Lancashire name overtops the common mass until that of Mr. Jeremiah Ainsworth, the grandfather of the gifted novelist, William Harrison Ainsworth, appears in the *Mathematical Magazine* for 1761. Mr. Ainsworth subsequently associated with Dr. Henry Clarke and Mr. George Taylor, two gentlemen of kindred tastes then resident in the neighbourhood of Manchester, and these veterans in science soon collected around them a goodly array of pupils and admirers, who subsequently occupied the foremost rank of the cultivators of pure geometry. Their influence and example resulted in the formation of a Mathematical Society at Oldham, in A.D. 1794, by Messrs. Abraham Jackson, William Hilton, William Travis, James Travis, and John Bardsley, whose members soon distanced those of the parent society in geometrical pursuits. The establishment of this society supplied the requisite impulse for the full development of this local geometrical taste, and no reasonable doubt can exist that the Manchester and Oldham Mathematical Societies were really the great promoters of the revival of the study of the ancient Geometry in Lancashire;—for during the latter half of the last century, and almost up to the present date, they have numbered amongst their members several of the most dis-

tinguished cultivators of ancient Geometry in modern times. "A cursory glance at some of our mathematical periodicals will readily furnish the names of Ainsworth, whose elegant productions in pure Geometry adorn the pages of the *Gentleman's* and *Burrow's Diaries;*—Taylor, the distinguished tutor and friend of Wolfenden;—Fletcher, whose investigations in the *Gentleman's Diary* and the *Mathematical Companion* entitle him to the highest praise;—Wolfenden, acknowledged by all as one of the most skilful cultivators of plane geometry of the last century;—Hilton, afterwards the talented Editor of 'that work of rare merit' the *Liverpool Student;*—and last, but not least, the distinguished Butterworth, whose elegant and extensive correspondence occupies so conspicuous a place in the *Student*, the *Mathematical Repository*, the *Companion*, the *Enquirer*, the *Leeds Correspondent*, the *Diaries*, and the *York Courant*. Besides these, who resided in the immediate neighbourhood of Oldham, we find the names of Mabbott, Wood, Holt, *(Mancuniensis)* Dr. Clarke, *(Salfordoniensis)* subsequently of the Royal Military College at Sandhurst, and author of *Perspective*, *Rationale of Numbers*, &c.; as then resident at Manchester, and in constant communication with Crakelt, Hutton, Lawson, Wildbore, and other editors of Mathematical periodicals; nor can it be doubted, from the evidence of existing documents, that the predilection evinced for the study of the ancient Geometry by these active members of the Lancashire School, exercised considerable influence upon the pursuits of such able proficients in other localities as Campbell, Cunliffe, Dalton, Davies, Gough, Lowry, Ryley, Whitley, Shepherd, and Swale." *(Notes and Queries*, No. 34.)

But it was not Lancashire alone that witnessed the revival of the ancient forms of geometrical investigation:—Scotland produced her Playfair, Leslie, and Wallace, whilst the Mathematical Society of London furnished its quota of pioneers in preparing the way for the phalanx of explorers who occupied these fields of research towards the close of the last and the

beginning of the present century. The names of Edwards, Gompertz, Hampshire, and Sanderson, suffice to show that the same spirit animated the operatives of Spitalfields which had already roused the hand-loom weavers of Lancashire to profitable action, whilst the fact of Mr. John Fletcher, a journeyman hatter, being at times a member both of the London and Oldham Societies,* connects the metropolitan with the provincial, and furnishes an instance of the means by which one Society could profit by the objects and designs of another, much more readily than by waiting for their uncertain development in the pages of the Mathematical periodicals.

During the same period, Mr. John Ryley, of Leeds, the "*Rylando*," the "*Ferdinando*," and the "*Mr. Brookes*" of the periodicals, laid the foundation of what Professor Davies not unaptly terms the "Yorkshire School of Geometers," (*Notes and Queries*, No. 57,) and more than ordinarily succeeded in diffusing a love for pure Geometry amongst the operatives in the West Riding of Yorkshire, which has since extended itself northwards, and found a genial home amongst the miners and engineers of Northumberland and the borders of Scotland. It is a singular circumstance that most of the ablest academic and non-academic Mathematicians and Philosophers of our times are natives of the North. Whewell, Sedgwick, Rutherford, Woolhouse, Fenwick, Tate, Hodgkinson, Finlay, (*Dunelmensis,*) Weddle, Elliott, Hann, Harley, Rawson, Whitley, Beecroft, Buckley, Tebay, and many others may be cited in proof of the assertion; and the fact has so frequently forced itself upon the attention of even casual

* Mr. Fletcher was admitted a member of the "Mathematical Society of Spitalfields," October 10th, 1795, as appears by the Minutes of the Society, now in the possession of the Royal Astronomical Society, and from which Mr. Williams, the Assistant Secretary, has kindly furnished me with an extract. Mr. Ogden, the present Secretary of the Oldham Society, also informs me that Mr. Fletcher became a member of that Society in 1803. His letters to Mr. Wolfenden, quoted in my *Memoir*, show that he always kept up an active correspondence with his Lancashire friends.

observers, that one of the Yorkshire geometers, *(Mr. Hopps,)* not long ago amusingly proposed for solution the problem of determining "*geometrically*, what property of the climate in the North of England causes so many of the natives to be good mathematicians."

No doubt much of this predilection for geometrical pursuits amongst the operatives of England, arises from the circumstance that the *nature* of the subject is peculiarly adapted to their ordinary occupations. The weaver at the loom,—the farmer in the field,—the mechanic in the shop,—or the miner in the drift, is too much occupied by *manual* labour to be able to *write out* long *analytical* investigations, but each can contemplate and deduce at pleasure the properties of a geometrical diagram, either *actually* constructed or *mentally* conceived. The farmer and the miner soon acquire the power of depicting vivid *mental* representations of the constructions necessary for their geometrical inquiries, and are thus enabled to carry on their processes of deduction even when buried in the mine or following the plough. The weaver and the mechanic can sketch their diagrams on a slate, and thus pursue their favourite studies whilst their hands and feet are almost instinctively engaged in their monotonous operations. In this manner many of the speculations of the Geometers of the Lancashire School are known to have been conducted. Nor is the practice at present by any means extinct; most of the profound investigations of Wolfenden and Butterworth, which appear in the *Mathematical Companion* and elsewhere, were composed almost word by word whilst contemplating the requisite diagrams suspended from the framework of their looms.

It is much to be regretted that so large a proportion of the subjects upon which the Lancashire Geometers exerted their powers relate to the *Construction of Triangles* with given data. By selecting a leading datum, and connecting it with others remotely dependent upon it, we may extend such

inquiries almost indefinitely; but owing to the want of some *general principle*, by which one construction can be derived from another, nearly all such speculations terminate in isolated problems, which, however much they may exercise the ingenuity of the student, are rarely found to repay the time and labour expended upon them.*

The publication of Newton's *Arithmetica Universalis* and the Appendix to Simpson's *Algebra* no doubt furnished the incentives to such a course of study, and almost every mathematical periodical for nearly a century testifies to the ardour with which the subject was cultivated. The fact of having solved all Newton's problems *geometrically* was made a matter for self-congratulation by Mr. Reuben Burrow. The Rev. John Lawson, Professor Leybourn, and Mr. John Farey published Synopses of *Data for the Construction of Triangles*, pointing out what had been effected and what still remained to be done in certain cases; yet, with perhaps one or two exceptions, no *general* principles have been elicited. Each geometer commences his analysis *de novo* for each isolated problem, and after deducing the construction for the *difference* from that for the *sum*, or *vice versâ*, most frequently abandons one method of investigation to adopt another equally unprofitable. The *germs* of many of the beautiful theories which form so conspicuous a feature in the writings of the Continental Geometers, are to be found in several of our early English periodicals. The leading properties of Transversals, Poles and Polars, Radical Axes, Poles of Similitude, the Complete Quadrilateral, Conjugate Section, &c. &c., occur in the *Diaries* and elsewhere, as has been frequently pointed out in my contributions to the "*History of Mathematical Periodicals*" in the *Mechanics' Magazine*.

Where it was or by whom Mr. Jeremiah Ainsworth received

* A variety of interesting and valuable observations on this subject may be found in Nos. IX. and X. of the late Professor Davies's "*Geometry and Geometers*," published in the *Phil. Mag.* for April and June, 1852.

the impulse which biased his mind in favour of Geometry, cannot perhaps now be ascertained; but, from his position in life and his subsequent connexions, it is not improbable that the Grammar School of Manchester had the honour of his education. He died in 1784, at the early age of forty-one, and hence at the time of his first appearance as a correspondent to the *Mathematical Magazine* he could not be more than eighteen years of age. In 1768 he answered most of the mathematical questions in the *Lady's Diary*, but probably from the circumstance of none of his solutions being printed at length he discontinued his communications to that periodical. At a later period we find him in correspondence with the Editors of the *Manchester Journal* for 1771, the *Gentleman's Diary* for 1782, the *London Magazine*, and *Burrow's Diary* from 1777 to 1782. His communications to the *Manchester Journal* prove him to have been well acquainted with astronomy, and involved him in a controversy with his neighbour Dr. Clarke, who however does not appear to have entered so deeply into the subject under dispute as his opponent. As a geometer, his merits were well known and appreciated by his contemporaries, so much so that the Rev. John Lawson, who contemplated the publication of a series of Solutions to the Theorems and Problems which usually pass under his name,* submitted his manuscript to Mr. Ainsworth for his judgment and corrections. What has become of this MS. collection I am unable to state, but the following account of its existence will not be without its interest, and may possibly lead to its discovery:—

"Manchester, Aug. 22nd, 1777.

"Rev. Sir,—I received your manuscript, &c., which I have examined carefully, and indeed not quite without effect; for I have found *three*

* It is not generally known that what are usually termed "*Lawson's Theorems*" were mostly taken, *without acknowledgment*, from Dr. Stewart's *Propositiones Geometricæ*. The first thirty-five Theorems are taken consecutively from Book I. of this work, and several of the others may be found in the same author's *General Theorems*.

quite false; viz., the Demonstration of a Theorem by Mr. Power, a Problem by myself, and another by Mr. Merrit. I have corrected my own, and Mr. Power will very easily do that for his own; but I think Mr. Merrit's incurable, without beginning again *de novo*. * * * But now to your Book. I have mostly corrected every thing as I went on, with a pencil, in the Book itself, or in the Plate, and which may easily be rubbed out if found necessary. * * * You may send the next when convenient.

"I am, yours, &c.,

"*The Rev. John Lawson,*
"*Swanscombe, Kent.*"

"JEREMIAH AINSWORTH.

The principal portion of Mr. Ainsworth's writings appear in *Burrow's Diary*. They relate to nearly every branch of Mathematics, and their acknowledged superiority gained for their author the "*Prize of Twelve Diaries*" for five successive years. In the *Diary* for 1777, Mr. Thomas Moss proposed for demonstration a property which in reality belongs to the *complete quadrilateral*, although enunciated merely for the case of the triangle. Its truth was very neatly proved by Mr. Ainsworth, Mr. John Burrow, the proposer, and several others, whose solutions are the more remarkable, since they all but formally state the leading properties of the complete quadrilateral, and add several to those already instanced under another form by La Hire and Maclaurin. In reference to Fig. 1, (see illustrative Diagram at end of Paper,) it is shown that:—

(1.) A B : B C :: A M : C P :: A D : D C;
and S Q : Q V :: S D : D V.

(2.) Q m = Q w, &c.

(3.) A C, a c, &c., pass through the point D.

(4.) The locus of the points N, n, &c., is the line T Q.

(5.) If D be such that S D is *conjugately* divided, in the same ratio will all lines as A D, a D, &c., be divided.

(6.) If Q m, Q M^1, be drawn parallel to D a, D A, cutting S c, S C, in m, M^1;—the locus of the points m, M^1, &c., will be a line parallel to T V.

Hence (1.)—*In every complete quadrilateral, each diagonal is conjugately divided by the two others.* (Carnot's *Essai sur la Théorie des Transversales.* Theor. VI. *Geom. de Position*, p. 282, Theor. VIII.)

(2.) *In every harmonic pencil, if a transversal be drawn parallel to any one line, it will be bisected by the other three.* (Maclaurin's *Gen. Prop.* § 20. Davies's *Hutton*, vol. i., Theor. 99.)

(3.) *The point* D *is fixed for all quadrilaterals having one diagonal* S V *constant, and the other a variable portion of* T Q. (Garnier's *Reciproques*, p. 104. Davies's *Transversals*, Prop. IX.)

(4.) and (5.) correspond to Carnot's *Essai*, Theor. VI. and VII.; also Davies's *Hutton*, vol. i., (2.) Theor. 99. (6.) is also a property worthy of notice.

The properties of the complete quadrilateral have been very successfully cultivated by the late Professor Davies. His *first* paper "On the Trapezium" was published in the *Philosophical Magazine* for August, 1826, and he afterwards resumed the subject in Clay's *Scientific Receptacle*, and in the sixth volume of Leybourn's *Mathematical Repository*.* In the latter work, taking for granted the property that "*circles described about the component triangles* STC, SAN, VAT, VNC, *intersect*

* For a detailed account of most of the published writings of the late Professor Davies, reference may be made to my article "*On English Mathematical Literature*" in the *Westminster Review* for April, 1851, and also to the *Educational Times*, No. 42.

in the same point L_1", (*Repository*, vol. i., p. 170,) he demonstrates that—

(1.) $< C L_1 A = < C S T = < A V T$.

(2.) $< N L_1 T = < C S T = < A V T$.

(3.) The centres M, N, S, R, of these circles, and also the point L_1, lie in the same circumference.

(4.) The feet of perpendiculars from L_1 upon the sides S T, S C, V T, V A, lie in the same straight line; besides various other relations of minor importance. (*Repository*, vol. vi., pp. 124—136; 229—234.)

The elegant property in (4.) has been extended to lines making equal angles with the sides, for the case of the triangle by Mr. Godward in Ques. 1731 of the *Lady's and Gentleman's Diary*, and for the quadrilateral by Mr. J. W. Elliott in Ques. 1847 of the same work;—Mr. Davies also enunciates, but does not prove, the curious properties "*that circles described upon the three diagonals have the same radical axis*," and that "*their centres range in the same straight line*." (See *Diary* for 1854-5. Ques. 1878.)

Henry Clarke, LL.D., was for many years one of the most distinguished ornaments of the Lancashire School. His versatile talents and extensive acquirements rendered him well adapted to occupy a prominent position in the world of Science, and his numerous publications bear testimony to the unceasing activity of his mind. To the *Lady's Diary* he communicated many elegant geometrical solutions to questions proposed by himself or his friends, and after the death of Mr. Ainsworth he was the principal supporter of *Burrow's Diary* under the assumed name of *Salfordoniensis*. Amongst his separate publications, those on *Perspective*, *Circulating Numbers*, and the translation of *M. Lorgna on Infinite Series*, are the best known; but a complete list comprises many others on Mathematics, Philosophy, Poetry, History, Languages, and General Literature. His acquaintance with the ancient and

modern languages gave him a decided advantage over most of his contemporaries, and rendered him able to profit by the writings of the Continental Geometers, at a time when most of their works were sealed books to the majority of English students. Another result of this intimacy was the translation of *Lorgna's Series*, previously noticed, which was dedicated to his friend Dr. Charles Hutton, and involved him in a controversy* with the celebrated John Landen, who, however, does not appear to be more distinguished for his profound acquaintance with the higher branches of Mathematics than for the acrimony he invariably displayed when replying to the statements of less gifted opponents.

During most of this period, Dr. Clarke was merely known as Principal of the "Classical and Mathematical School in Salford, Manchester," but he subsequently filled the offices of "Prælector in Mathematics in the Manchester College of Arts and Sciences," and "Professor of Geography, History, and Experimental Philosophy" in the Royal Military College at Marlow. He was also frequently in correspondence with most of the leading Mathematicians and Philosophers of the day, whose letters he proposed to publish in an account of his own Life and Writings, and was even proposed to be elected a Fellow of the Royal Society, but was rejected by Sir Joseph Banks and his friends, ostensibly on the ground of his being "*only a Schoolmaster*," but more correctly, perhaps, on account of the feuds which then existed between the Mathematicians and the Naturalists belonging to the Society.

In common with those of most of his contemporaries, a consi-

* This noted controversy appears to have given rise to the following publications:—

1. *M. Lorgna on Infinite Series.* Translated by Henry Clarke.
2. *Observations on Converging Series.* By John Landen.
3. *Supplement to M. Lorgna's Series.* By Henry Clarke.
4. *An Appendix to "Observations on Converging Series."* By John Landen.
5. *Additional Remarks on M. Lorgna's Series.* By Henry Clarke.
6. *A Supplement to "An Appendix to 'Observations,'" &c.* By John Landen.

derable portion of his geometrical writings relate to the Construction of Triangles from given data, as may be seen by a reference to the *Lady's Diary* for the years 1774—1784, and his analyses of these and similar problems afford abundant proofs of his intimate acquaintance with the best forms of the Greek Geometry. The same fact is also obvious from his *Rationale of Circulating Numbers*, (Lond. 1777,) where he gives corrected solutions to a number of geometrical and other questions which had been incorrectly treated in Malton's *Geometry*, the *Town and Country Magazine*, the *Lady's Diary*, and elsewhere; and at the close of the work "some *new* Geometrical Propositions" are added, which are the more deserving of notice since they make a nearer approach to *systematic* investigation than any other portion of the Lancashire geometry with which I am acquainted; Swale's *Apollonius*, the *Lineal Sections*, and the "*Modern Geometry*" in the *Student* alone excepted.

Of the many Geometers of the Lancashire School, none have become so much distinguished as Wolfenden and Butterworth. They both belonged to the Oldham Mathematical Society, and throughout the course of their long lives resided in the immediate locality. Both of them were nursed and reared in poverty;—both had to struggle with its difficulties through life;—and both in old age would have had to endure its keenest privations had not the pecuniary assistance of the members of the "Manchester Literary and Philosophical Society" softened the rigours of stern necessity, and freed the last days of these "noblemen of nature" from all anxiety respecting the ordinary necessaries of life. The names of Messrs. Hodgkinson, Binney, and Moore stand prominent in this act of mercy, and I have the satisfaction of knowing that their efforts in behalf of "scientific men in humble life" have not been unappreciated by many whose thanks have formed their only means of recompense.

Several of the earliest of Mr. Wolfenden's contributions to Mathematical Science may be found in *Burrow's Diary* for 1781, and in the *Gentleman's Diary* for 1783. In both of these publications his aptitude for geometrical investigations appears conspicuous, and although particular circumstances subsequently led him to enter more fully into *mixed* Mathematics than the majority of his contemporaries, yet even in his mechanical and hydrostatical inquiries we find evident traces of a mind strongly biased in favour of the forms of pure Geometry. His contributions to the *Mathematical Companion* are principally on mechanical subjects, the most remarkable of which relate to the noted question respecting the "*Exciseman's Staff*," and kindred problems which had been erroneously treated in the *Gentleman's Diary*.* His later practice was to attempt only those problems in which others had either met with difficulties or had arrived at erroneous results, and hence many of his solutions partake of a correctional character, not always pleasing to the editors of periodicals and the writers assailed. His favourite authors were Newton, Simpson, and Emerson; the *Select Exercises*, he ever maintained, were "worth their weight in gold," and the influence of the *Principia* may be inferred from the fact that most of his geometrical inquiries in Whiting's *Delights*, and elsewhere, are based upon the Method of Prime and Ultimate Ratios. To the *Liverpool Student*, partly edited by his former pupil, Mr. William Hilton, he was a constant contributor; and for many years supplied the "Tide Tables for the Port of Liverpool" in Lang's *Original Liverpool Almanack*. Under the signature "Senex," he occasionally appears in Leybourn's *Repository*, and the reproposal Qof uestion 400 in the *Mathematical Companion*, under this assumed name, led to the production of a solution by his friend and former pupil, Mr. Butterworth,

* For a most interesting discussion of this question, when *friction* is taken into consideration, reference may be made to Vols. 56 and 57 of the *Mechanics' Magazine* for 1852.

which has usually been considered as the masterpiece of this able Geometer. On the whole, however, it may reasonably be doubted whether the *published* writings of Mr. Wolfenden influenced in any great degree the increasing taste for the ancient Geometry;—they are, strictly speaking, too few and too diversified as to subject to produce any marked effect, but *local tradition* assigns a wider influence to his private tuition. Many of his earlier pupils subsequently became distinguished for their mathematical attainments, and their proficiency in pure Geometry has produced the general conviction that their tutor was really one of the great promoters of the revival of the study of this interesting branch of Mathematical Science.

Mr. Butterworth commenced his long and successful career in the pages of the *Liverpool Student* for 1797, but his *geometrical* propensities do not begin to manifest themselves before the publication of the third number for 1799. On the discontinuance of this work he transferred his support to the *Gentleman's Mathematical Companion*, where he first appears in 1801, and continued one of its ablest and most extensive contributors for upwards of twenty years.* He is confessedly the Prince of the Lancashire Geometers both for variety and extent, for were the whole of his correspondence to this and the other periodicals previously enumerated to be collected, it would form several bulky volumes on Geometrical Analysis.

The *Construction of Triangles from given data* would indeed form a conspicuous feature of such a collection; but properties of the Conic Sections and Triangles, Problems on Tangencies and Loci, Sections of Ratio and Space, Inclinations and Porisms, would appear at intervals in considerable variety,

* For more extended sketches of the lives and writings of Messrs. Wolfenden, Butterworth and Kay, I may refer to Fielding's *Historical Gleanings in South Lancashire*, where my "Memoirs" of these distinguished Geometers are reprinted, with additions. I am indebted to the kindness of Mr. E. W. Binney for much interesting information respecting the late Mr. Butterworth, and also to Mr. Henry Buckley and Mr. William Lees, of Hollinwood, for similar information respecting Messrs. Wolfenden and Kay.

and mostly treated in a style which for originality and elegance would certainly have done no discredit to either the "Author of the *Elements*," or the "Great Geometer of Perga." Very few, however, of these interesting discussions are presented in a *connected form;* almost all the properties belonging to any particular class are given as isolated questions, and often at considerable intervals, so that no small amount of labour will be requisite whenever an attempt is made to reduce any of these scattered theories to a regular system. Isolation and promiscuous arrangement are, indeed, among the characteristics of the Geometry of the Lancashire School, and nowhere is this more distinctly exhibited than in the *Mathematical Companion;* its members, as a body, in common with many others, never appear to have become sensible of the value of systematic research, nor did they attribute much importance to arranged collections of the properties of geometrical figures. Hence, although the Symmetrical properties of Plane Triangles,—the Harmonical division of Lines,—the principal properties of Lines passing through the same point, or of points ranging in the same Straight Line,—the properties of Circles of Tangential Ratio, &c. &c., may be found scattered throughout their writings, scarcely an attempt was made to classify any of these results, before the appearance of Swale's *Geometrical Amusements* and his *Apollonius,* beyond what we find effected in the case of "*Lineal Sections*" and the "*Modern Geometry*" of the *Student.* The former of these articles is well known to relate to the determination of *two lines,* by having certain relations given,* and is mostly due to Mr. Knowles, of Liverpool; the latter article contains the additions made

* To determine two lines, geometrically, when:—

1. Their sum and difference;—
2. Their sum and rectangle;—
3. Their sum and ratio;—
4. Their sum and sum of their squares;—
5. Their sum and difference of their squares;—
6. Their difference and rectangle;—&c. &c.; are given.

by the Lancashire Geometers to the properties of "*Halley's Diagram*," which first made its appearance, with fewer lines, in Jones's *Synopsis Palmariorum Matheseos*, page 244, Lond. 1706.

This important assemblage of lines subsequently found its way into *Burrow's Diary* for 1777, where several additional properties are given; and about the same period, Dr. Henry Clarke, in his *Rationale of Circulating Numbers*, added a "new proposition" to the number already known, and pointed out its uses in drawing the line A F such "that either the sum, difference, ratio, rectangle, sum of the squares, or difference of the squares of A G and G F, may be of a given magnitude;" the point A being at the intersection of two given circles, and G F the part between the respective circumferences. The utility of these properties in the construction of several classes of geometrical problems, led Mr. Lowry to reconsider the subject at considerable length in the original series of Leybourn's *Repository*, where also another class of properties is elegantly deduced by "Mr. M. A. Harrison," who is generally supposed to represent either Mr. J. H. Swale, of Liverpool, or Mr. Lowry himself. In this state of forwardness the diagram was introduced by Mr. Knowles into the first number of the *Student*, and under the title of "Modern Geometry," sixty-two regular propositions and their corollaries, most of them original, were furnished by his correspondents during the progress of the work.

With reference to Fig. 2, if we suppose the triangle A B C to be inscribed in the circle A H C B F, R its centre, O the centre of the inscribed circle, O U parallel to A B, and the rest of the lines as in the diagram, Mr. Wolfenden proves that:—

(1.) $CO \cdot OF = OL \cdot HF = 2Rr$. (*Mod. Geom.*, Prop. 35; Davies's *Horæ Geom. Diary*, 1835, Prop. XI.)

(2.) $AC \cdot CB = CO\,(FO + FC)$. (*Mod. Geom.*, Prop. 36.)

(3.) $CF \cdot IQ = \frac{1}{4}(AC - CB)^2$. (*Mod. Geom.*, Prop. 37.)

(4.) $CF(CV + VB) = CB(CZ + ZF)$. (*Mod. Geom.*, Prop. 38.)

(5.) $HE : EF :: CB^2 : mn^2$. (*Mod. Geom.*, Prop. 39.)

Most of the propositions previously to those just enumerated were collected by Mr. Knowles under the signatures of "Non Sibi" and "N. Selwon;" several of the subsequent ones most probably belong to Mr. Hilton, since they bear the initials "W. H."; Messrs. Nicholson and Wright also furnished a considerable number of properties, and the last number of the work contains Mr. Butterworth's contributions to the common stock. He there proves that:—

(1.) $HO^2 = FH(HU - EU)$; (*Mod. Geom.*, Prop. 60.)

(2.) $IL(AC - CB) = KL(AI - IB)$; (*Mod. Geom.*, Prop. 61.)

(3.) $LK^2 = DH(DU - EU)$; (*Mod. Geom.*, Prop. 62).

Had the *Student* been continued for a longer period, there is little doubt that Mr. Butterworth would have added considerably to the list of properties of the general diagram, for in later years he gave several Theorems of the same class in the *Mathematical Companion*, which are by no means unworthy of notice. In Ques. 352 of this work, by dropping the perpendiculars upon the sides from A and B to meet HF in T and W, and making $Ew = EF$, he shews that $AC : BC :: Ww : Tw$; and in Ques. 418 he furnishes a demonstration of Lhuilier's property that—

$r\, r_1\, r_2\, r_3 = \Delta^2$; where r, r_1, r_2, r_3, are the four radii of contact respectively. (Davies's *Horæ Geom. Diary*, 1835, Prop. X.)

If we now put O, O_1, O_2, O_3, for the centres of the inscribed and escribed circles, Mr. Butterworth further shews, in Ques. 470, that—

$HO_1 = HA = HB = HO_3$; and hence "*the centres* O_1, O_3, *are always in the circumference of a circle whose*

centre is H *and radius* H A, *wherever the point* C *is taken in the arc* A H B." (Davies's *Horæ*, Prop. XXVII., *Diary*, 1842.) In Questions 544, 621, 664, and 723, he again recurs to this attractive subject, and by purely geometrical processes demonstrates that:—

(1.) $r_1 + r_2 + r_3 = 2D + r$. (*Horæ, Diary*, 1835, Prop. IX.)

(2.) $RO^2 + RO_1^2 + RO_2^2 + RO_3^2 = 3D^2$; a "remarkable theorem." (*Horæ, Diary*, 1835, Prop. XIX.)

(3.) $O_1O_2^2 + O_2O_3^2 + O_3O_1^2 = 4D\,(r_1 + r_2 + r_3)$. (*Horæ, Diary*, 1842, Prop. XXVII.)

(4.) $OO_1^2 + OO_2^2 + OO_3^2 + O_1O_2^2 + O_2O_3^2 + O_3O_1^2 + RO^2 + RO_1^2 + RO_2^2 + RO_3^2 = 15D^2$. (*Horæ, Diary*, 1835, Prop. XIX. and Cors.)

On reviewing the preceding propositions from the *Student*, and also Mr. Butterworth's demonstrations of these more important properties, the want of a *uniform system of notation* is at once apparent. This deficiency was in part supplied by one or two of the more analytically-minded correspondents to the *Companion*, and also by the late Professor Davies, in his paper "On the Symmetrical Properties of Plane Triangles," printed in the *Phil. Magazine* for July, 1827, shortly after the appearance of the last of Mr. Butterworth's Theorems; but the defect was not entirely removed until the happy idea of treating *all the sides of the triangle as preceding writers had treated the base only*, led him to commence the "*Horæ Geometricæ*" in the Appendices to the *Lady's Diary* for 1835-6-42, which have since been productive of a series of symmetrical results, no less numerous than elegant, in the able hands of Weddle and Elliott. Nor is the subject by any means exhausted. The pages of the *Lady's and Gentleman's Diary*, and other mathematical periodicals, frequently contain interesting combinations and extensions of the formulæ established by the preceding writers, and but little difficulty would be encountered in adding considerably to their number.

If, for instance, we take the values of the sides and of the lines A O, B O, C O, &c., as given in the *Horæ Geom.* (7) and (8), *Diary*, 1843; we have—

$a^2=(r_2+r_3)(r_1-r)$; $b^2=(r_1+r_3)(r_2-r)$; $c^2=(r_1+r_2)(r_3-r)$.

$\therefore a^2+b^2+c^2 = 2(r_1r_2+r_1r_3+r_2r_3-rr_1-rr_2-rr_3)$.....(1).

Again: $\alpha^2=(r_2-r)(r_3-r)$; $\beta^2=(r_1-r)(r_3-r)$; $\gamma^2=(r_1-r)(r_2-r)$; whence

$2\alpha^2+2\beta^2+2\gamma^2 = 2r_1r_2+2r_1r_3+2r_2r_3-4rr_3-4rr_2-4rr_1+6r^2$.

But $2d(D-r) = +2rr_3+2rr_2+2rr_1-6r^2$.

$\therefore 2\alpha^2+2\beta^2+2\gamma^2+2d(D-r) = 2(r_1r_2+r_1r_3+r_2r_3-rr_1-rr_2-rr_3)$.....(2).

Now (1) and (2) are identical, and

$\therefore a^2+b^2+c^2=2\alpha^2+2\beta^2+2\gamma^2+2d(D-r)$; whence "*the sum of the squares of the sides of any plane triangle is equal to twice the sum of the squares of the lines from the inscribed centre to the angular points, added to twice the product of the inscribed diameter into the difference between the circumscribed diameter and the inscribed radius.*" The enunciation of this property is due to Mr. Henry Buckley, of Delph, and would not be easy to demonstrate by the ordinary forms of the Ancient Geometry.

The properties of what the late Mr. J. H. Swale has very appropriately termed "*circles of tangential ratio*," appear to have received a considerable share of attention from the Lancashire Geometers. In the third number of the *Mathematical Companion*, Mr. John Fletcher proposed for consideration the determination of a *fourth* point D, when "three points A, B, C, being given, it is required that $m.AD^2$; $n.BD^2$; $p.CD^2$; shall have given differences;"—and this somewhat difficult problem was very elegantly constructed and demonstrated by Mr. R. Nicholson, of Liverpool, and

also by the proposer, but the former gentleman's solution is the more remarkable on account of the following "curious Theorems on Circular Loci" which he enunciates at the close of his investigation:—

(1.) *If two lines be drawn to meet each other, one from a given point, and the other a tangent to a given circle, such, that they shall have a constant given ratio, but not that of equality, the locus of their points of intersection is a circle.*

(2.) *If the tangents of two given circles be drawn to meet each other and have a constant given ratio, but not that of equality, the locus of their points of intersection is a circle.*

The *first* of these Theorems is obviously that case of the *second* when one of the circles is reduced to a point;—the locus in *both* cases is the "circle of tangential ratio," and if the given ratio becomes that of the radii of the two circles, we obtain the *circle of similitude* as a particular case of the general Theorem. (Davies, *Diary*, 1851, Prop. XII.) The case, when the given ratio is *one of equality*, is specially excepted by Mr. Nicholson, but it was subsequently proposed for an independent solution in the *Companion*, and also forms a corollary to Mr. Lowry's solution of (2) in Ques. 117 of the New Series of the *Repository*. In both the places cited the locus is shewn to be a right line, since termed the *radical axis* of the two circles, and is, in fact, that case of the general locus *when the radius of the circle of similitude, or of the circle of tangential ratio, becomes of infinite magnitude.*

The publication of Lowry's Lemma and Corollary in the *Repository* appears, by a reference, to have led Mr. Swale to enter more fully into the subject of Tangential Ratio than had been done by his predecessors. In his MS. remains, (vol. vii., pp. A to L.) he constructs all the principal cases, and extends the inquiry to that of determining "the point P,

(Fig. 3.) in a line M N of *any* order, such, that drawing the tangents P V, P T, to two given circles (A) and (B), they may have a given ratio;" but he does not particularise the interesting cases just noticed, nor do I find in any of the writings of this distinguished geometer* the least intimation of his being aware of what the Continental Geometers had effected by means of Radical Axes and Circles of Similitude.

When two circles (A), (B), and the tangential ratio are given, he determines the circles of tangential ratio very elegantly by taking "rad. A T : ⊥ H I :: ⊥ A D : B H, in the given ratio, and drawing (to the circle through H, centre B), the tangents D V', D T', meeting A B in K and L:—then K L is the diameter of the circle required," (MSS., vol. vii., page G.) which construction, when the ratio becomes that of A T : B V, reduces to the simple process of describing a circle on the diameter of similitude, determined by the direct and inverse common tangents to the two given circles. (Davies, *Diary*, 1849, Prop. I.) The intersection of the circle thus determined with the line M N, of *any* order, furnishes a solution of the problem proposed by Mr. Swale.

If we now suppose the circle (A), the circle of tangential ratio (Q), the ratio of the tangents $m : n$, to be given, and it were required to determine the other circle (B), we have obviously the *converse* of the preceding general locus, which

* An account of the peculiar characteristics of Mr. Swale's geometrical writings has been given by Professor Davies, in No. VII. of his "*Geometry and Geometers*," in the *Phil. Magazine* for June, 1851; and a description of his MSS. will be found in my "*Additions to the late T. S. Davies's Geometry and Geometers*," in the *Phil. Magazine* for July and September, 1852. A short memoir of his life may also be seen in the *Mechanics' Magazine* for March, 1852. Mr. Swale, although so long resident in Liverpool, belonged to the Yorkshire School of Geometers, and was one of the ablest of Mr. Ryley's pupils. His able townsman, the late Colin Campbell, Esq., also deserves honourable mention amongst the geometers of his time, but his elegant "*Lucubrations in Mathematics*" do not come within our scope, since their author was a native of Westmoreland, and received his education under Mr. Howard, of Newcastle-upon-Tyne.

was proposed for solution by Mr. Butterworth as Ques. 699 of the *Mathematical Companion* for 1826. It is there shewn by Professor Gill, Dr. Rutherford, Mr. Wright, and the proposer, that if A B be taken, such "that A Q : Q B :: m^2 : n^2, and with B as centre and radius equal to the side of a square whose area

$$= BV^2 = \frac{m^2}{n^2} AT^2 + \left(\frac{m^4}{n^4} - \frac{m^2}{n^2}\right) AQ^2 - \left(\frac{m^2}{n^2} - 1\right) QL^2,$$

a circle be described, it will be the one required;" and the general formula is readily adapted to the case of similitude, where $m : n$ is also the ratio of the radii of the given circle and that to be found. If $m = n$, we have—

$$QL^2 = \frac{AT^2 - BV^2}{0} = \infty, \text{ and consequently}$$

the radical axis is really a circle of similitude to an infinite radius.

In another portion of the *Companion*, Mr. James Cunliffe, of Bolton-le-Moors, a Lancashire geometer of ability,* considered the cases of the Loci when:—

(1.) The circles are concentric and the tangents form with each other a given angle. (Ques. 202.)

* In addition to those previously enumerated, the names of Mr. Jonathan Mabbott, of Oldham, but latterly of Manchester, and Mr. Thomas Bazley, of Bolton, ought to be placed on record as Lancashire mathematicians of considerable eminence. The writings of the former gentleman appear in Whiting's *Scientific Receptacle* and *Geometrical Delights*, the *Lady's and Gentleman's Scientifical Repository*, the *Diaries*, the *Leeds Correspondent*, &c., and evince his thorough acquaintance with the Doctrine of Series and the higher branches of pure Mathematics. Mr. Bazley's correspondence occurs in the earlier portions of Leybourn's *Mathematical Repository*, New Series, the *Gentleman's Mathematical Companion*, &c., where he occasionally assumed the signature of "Helozam Satby," an obvious anagram of his real name. His favourite subjects appear to have been Geometry, Mechanics, and the more abstruse parts of pure and applied Science;—his superiority in these subjects procured him several well-earned prizes in both the periodicals previously mentioned. Mr. William Smith, of Liverpool, was also another excellent Lancashire geometer. His investigations in the *Repository*, the *Companion*, and the *Student*, bear testimony to his profound aquaintance with the Ancient Geometrical Analysis.

(2.) When the circles are concentric and the sum of the tangents is constant. (Ques. 205.)

(3.) When the circles are *any how posited* and the sum of the tangents is constant. (Ques. 212.)

The Loci in cases (1) and (2) are shewn to be circles concentric with the given ones, and the locus of (3) is an ellipse;—when in (2) the *sum of the squares* of the tangents is constant, Dr. Harvey and Mr. Butterworth have proved in the *Boston Enquirer*, Ques. 72, that the locus is still a concentric circle; but if the same change is made in the data of (3), Mr. W. S. Eyres, of Liverpool, author of an *Essay on Geometrical Analysis*, has shewn in Ques. 66, *ibid*, that the locus then becomes a circle, and if the *difference* be substituted for the *sum*, we have then the locus a right line which coincides with the *radical axis* when $PT^2 - PV^2 = O$, and with the *bisectant axis*, (*Diary*, 1853, p. 79.) when $PT^2 - PV^2 = 2(AT^2 - BV^2) = 2(R^2 - r^2)$.

Mr. John Kay, of Royton, near Oldham, was one of the most distinguished of Mr. Butterworth's pupils. His questions and solutions in the *Gentleman's Diary*, the *Enquirer*, the *Leeds Correspondent*, and the *Mathematical Companion*, are not very numerous, but they are usually characterised by peculiar elegance and originality. Nor did he confine himself to geometrical speculations alone, for in the *Companion* and elsewhere we find him as the proposer and solver of some interesting problems in Statics and Dynamics. His chief strength, however, lay in pure Geometry, and from the masterly specimens he has left us of his skill in the higher branches of the Ancient Analysis, it would seem that he had not failed to profit by the instructions of his able tutor. Several curious properties of the Circle and the Conic Sections follow from his investigations, and in the difficult subject of Porisms he had but few competitors. The pages of the *Mathematical Companion* contain the majority of his contributions to this interesting branch of geometrical research;—his solution of

a Problem of this class gained him the *prize* in that work for the year 1822, and in conjunction with Mr. Butterworth he contemplated a separate publication on the subject of this celebrated Enigma of antiquity, but early death prevented the fulfilment of this design. In common with Mr. Butterworth and Mr. William Simpson, of Bolton-le-Moors, he had formed a clear conception of the *real nature* of these very general inquiries, and had he lived to complete his intentions, his publication would no doubt have contributed to remove some of the difficulties relating to Porisms which have formed an obstacle to Geometers from the time of Pappus down to the present day.

Dr. Simson and Professor Playfair indeed did much to dispel the cloud of obscurity which enveloped the subject, but, as Professor Davies well remarks, "the *great generality* of Simson's definition of the Porism has created much difficulty in apprehending its meaning. It may reasonably be doubted whether any Geometer ever acquired a distinct and complete idea of the Porism from Simson's definition of it;—just as it may be doubted *whether the Porism itself was originally discovered as an independent form of Proposition.* Yet it does happen that when the *full* idea is once gained, we feel that Simson's definition expresses it most completely and generally."

When a Porism is actually stated for solution, several methods of proceeding obviously present themselves. We may, for the purposes of analysis, suppose the Porism to be true, and by making two or more statements of the hypothesis, general or particular, as best suits the purpose, thus get rid of the indeterminates, as is done by Dr. Simson in his *Opera Reliqua;*—or by *one* statement and taking advantage of the *law of continuity* in extreme cases, as is done by Playfair in Art. 24 of his *Essay;*—or by *one* statement and *assuming* the things affirmed to be given as *actually given and constant,* as is done by Noble in the *Mathematical*

Companion for 1806;—or by reducing the porismatic property said to exist into the form of an equation and then treating it by the Method of Indeterminate Co-efficients, as is done by Gompertz, Epsilon, Baker, and Rangeley in the *Companion*, Galloway in the *Repository*, Davies in the *Mathematician* and in the *Edinburgh Transactions*, and more recently still by Gompertz again in his valuable *Hints on Porisms*, lately published. When by any of these means the entities required to be found, *have been found*, the requisite Constructions are indicated by the process, and the Demonstrations of the Porisms are reduced to those of ordinary Indeterminate Theorems.

The principal Porisms which engaged the attention of the Lancashire Geometers occur in the concluding volume of the *Mathematical Companion*. Three of them form the Prize Questions for the years 1822-3-4, and were severally proposed by Mr. Lowry, under the signature of "P. P.," and Mr. Kay. Did space permit, both the algebraical and geometrical solutions are well worthy of transcription, as specimens of the modes in which such inquiries may be treated; but as I am concerned only with those by Lancashire Geometers, the *enunciations* and *constructions* must suffice for the present occasion.

Porism.

Proposed by "P. P.," *Mr. John Lowry.*

"Two points and a circle being given by position, two straight lines may be found which will also be given by position, such, that if from the given points two straight lines be drawn to any point in the circumference of the circle, the rectangle contained by these lines will be a mean proportional between a certain given space and the rectangle contained by the perpendiculars drawn from that point upon the straight lines which are to be found."

Porismatic Construction. By Mr. John Kay.

"Let G Q r R P be the circle,* and A, B, the points given by position; through the centre O draw A C R n, making R n = 2 A Q, and divide A Q in S, so that S Q . Q n = A Q^2; draw S Z perpendicular to A n, and S Z will be one of the lines. In the same manner draw B P O m, making $m r$ = 2 B P, and divide B P in y, so that y P — P m = B P^2, and draw the perpendicular $y w$, which will be the other line." (*Math. Comp.*, Ques. 570.) The construction is similarly given by Messrs. Butterworth and Simpson; the latter of whom shews that the Porism is true for any number of points and lines.

Porism.

Proposed by "P. P.," Mr. John Lowry.

"Three circles, having their centres in the same straight line, being given by position, two straight lines may be found which will also be given by position, such, that if from any point in the circumference of one of the circles tangents be drawn to the other two, and perpendiculars be demitted from the same point upon the lines to be found, the rectangle of the tangents shall be a mean proportional between the sum of the squares of the two perpendiculars and a certain given space."

Porismatic Construction. By Mr. William Simpson.

"Let O c, F f, be the radii of the circles, to which tangents are to be drawn, A S that of the other, A S B its diameter. From S, towards O and F, apply S d, S c, such that S d . S O = S c . S F = S A^2. Bisect d O and c F at h and g, from which points towards S apply h G and g H, such that 2 O S . h G = O c^2, and 2 S F . g H = F f^2. On G H as a diameter let a circle be described to cut perpendiculars erected at A and B, at C and E, and D and F. Join D C and F E to meet

* The Figures to these Constructions may readily be supplied by the reader.

at P. Demit B q perpendicular to P D, and on D F apply B K and B L = B q. Join P K and P L, which are the lines to be found. On P L demit the perpendicular B m, and take S^3 such that $BD^2 : Bm^2 :: S^3 : 2OS . SF$, and S^3 is the space." *(Math. Comp.*, Ques. 606.)

Mr. Simpson remarks that his demonstration points out solutions to the following Problem and Porism:—

(1). "Three circles given in magnitude and position, whose centres are in the same right line, it is required to find a point in one of them, such that tangents being drawn to the other two their rectangle may be given."

(2). "Two circles, one included within the other, being given in magnitude and position, two right lines also given by position, may be found, such, that if from any point in the lesser circle perpendiculars be demitted on the lines so found, and through the same point an ordinate to the greater, the sum of the squares of the perpendiculars will have a constant ratio to the square of the ordinate."

Porism.

Proposed by Mr. John Kay.

"A and B are given points in the arc of a given semicircle to which tangents are drawn to intersect in D; now a right line may be found, such, that if perpendiculars be demitted from any point O in the arc A B, upon the lines A D, B D, the sum of the squares of those perpendiculars with r times the square of the perpendicular from the point O upon the line to be found, will be a constant magnitude; r being a constant quantity whose value is to be found from the data."

Porismatic Construction. By the Proposer.

"Generalise the proposition by taking the lines D A, D B, equidistant from C, the centre of the whole circle. Draw $z x$ parallel to D A, to meet D Z C in the point z of the periphery; draw $z m$ perpendicular to D z C P, and from P,

the point where it cuts the circle, draw P Q parallel and = $2 z m$. Through Q draw $x Q u$, to make the $< P Q x = < x z P$; lastly, bisect $z x$ in F by drawing the line E F H parallel to $z m$, which will be the line required." (*Math. Comp.*, Ques. 639.)

Mr. Butterworth, at the close of his demonstration, remarks that, "if there be two lines parallel to A D and B D, and at equal and given distances from them, a right line may be found, such, that the sum of the squares of the perpendiculars demitted from any point of the arc A B, upon the lines A D and B D, together with r times the square of the perpendicular upon the line to be found, will be a constant magnitude."

Porism.

Proposed by Mr. Thomas Baker.

"Three circles being given in magnitude and position, it is required to find the magnitude and position of another circle, such, that if tangents be drawn from any point in the circumference of one of the given circles to the other three, the sum of the squares of the tangents to the two given circles may be equal to the square of the tangent to the circle which is to be found."

Porismatic Construction. By Mr. Butterworth.

"Let O, P, Q, be the centres of the given circles; join P Q, and bisect it in C, and join O C, which produce till C R = O C; then with centre R and radius equal to the side of a square = $2 O C^2 + P F^2 + Q G^2 - O E^2 - 2 Q C^2$, describe a circle, and it will be that required." (*Math. Comp.*, Ques. 657.)

Mr. Wright, in his solution to this Porism, considers the Lemmatical Problem of "having three circles given in position and magnitude, to determine the *locus* of a point from which tangents being drawn, the sum of the squares upon two of

them shall be equal to the square upon the third tangent;"—and then, by considering this locus *(a circle)* and the circle from which tangents are drawn *to coincide*, he determines the required circle as in Mr. Butterworth's construction.

Porism.

Proposed by Mr. Charles Gill.

"Two straight lines and a circle are given in position, and the lines joining the centre of this circle and the centres of two other circles are also given. It is required to find the position and magnitude of these circles, so that if from any point in the circumference of the given circle, perpendiculars upon the lines, and tangents to the circles, be drawn, the rectangle of these tangents may always be a mean proportional between a certain given space and the rectangles of the perpendiculars."

Porismatic Construction. By Mr. Butterworth.

"Let O be the centre of the given circle, and D E and F G the lines given by position. From O demit O E and O G perpendicular to D E and F G in E and G:—upon O E and O G take O P and O Q equal to the given lines, and bisect them in K and L; then take K R and L S = third proportionals to 2 O P and the radius of the circle, and = 2 O Q and the said radius, and with the centres P and Q, and radii equal to sides of squares which are equal to 2 P O . E R, and 2 O Q . L S, respectively, describe two circles, and they will be those required." *(Math. Comp.*, Ques. 680.) Mr. Charles Holt also gives an Analysis of this Porism, from which he deduces a construction similar to the preceding.

Porism.

Proposed by Mr. Butterworth.

"Having given an ellipse, and a point in one of its axes, a right line may be found, such, that if any right line be

drawn through the given point, and from the points where it meets the curve perpendiculars be demitted upon the line to be found, their rectangle will be a constant magnitude."

Porismatic Construction. By Mr. Charles Holt.

"Let P be the given point in the transverse axis A B of the given ellipse A D B C; O its centre. Erect P K perpendicular to A B; apply O K = O A; make O L = O P; join L K, perpendicular to which draw K H to intersect A B produced in H; then through H draw G H I perpendicular to A B, and G I will be the line required." (*Math. Comp.*, Ques. 700.) Mr. Butterworth also gives a construction of this Porism.

PORISM.

Proposed by Mr. John Kay.

"Given the points C, D, A, B, in the same straight line. Now a straight line may be found, such, that any ellipse being described upon A B, as its axis, tangents drawn from C, D, will intersect in the line to be found."

Porismatic Construction. By Mr. Butterworth.

"Upon A B as a diameter, describe a circle, to which from C and D, draw the tangents C F and D S, intersecting each other in P, and through the point P draw the indefinite perpendicular E P, and it will be the line required." (*Math. Comp.*, Ques. 702.) Mr. Holt also gives an elegant Analysis and Construction.

It would not be difficult to enlarge considerably on this and other interesting topics, but the specimens already adduced may suffice to shew that the Lancashire Geometers had caught the true spirit of the Ancient Analysis. At the same time it cannot be doubted that they failed to profit to the extent they might have done by the fragments of systematic research

preserved to us in the *Mathematical Collections of Pappus*, or scattered throughout the pages of our own Mathematical periodicals. Many of the most attractive theories of modern times were evidently within their reach, and not unfrequently engaged a portion of their attention, but they suffered themselves to be led away by comparatively unimportant objects, and expended those energies upon isolated questions which ought to have been directed to *original and systematic* inquiries. M. Chasles has recently shewn in his *Traité de Géométrie Supérieure*, that *Anharmonic Ratio*, on which all Modern Geometry is found to hinge, was distinctly understood by the later Greek Geometers, and it is also under the same form to be found in several of our Mathematical journals; but previously to the appearance of his *Aperçu Historique*, in 1837, no one had been able to see its importance as a fundamental principle in Geometry. The comparative inadequacy of the *methods* employed by these otherwise able men, when applied to the higher branches of Geometry, will no doubt account for the fact that of late years the taste for the strict forms of the Ancient Analysis has much declined, even in Lancashire and in the North of England. Very few of those who flourished in the palmy days of the *Companion* are now in existence, and as the old Geometers, one by one, pass from the scene, their places are supplied by others who prefer the more powerful co-ordinate methods to those antiquated processes which at best can only accomplish, by a series of gradations, what follows at once from the general expressions of Modern Geometry. But it must not be imagined that we ought by any means to discard the Ancient Analysis altogether. The University of Cambridge is our best guide on mathematical studies, and she very properly insists upon a due acquaintance with both Euclidean and Cartesian principles; the former as a mental discipline;—the latter as a more powerful instrument

of research; and such is undoubtedly the only legitimate course which the student can pursue with advantage.

Dr. Stewart's determination of the *Sun's Distance*, and Sir John Leslie's *Geometry of Curve Lines*, present two memorable instances of Geometry as applied to subjects for which it is ill-adapted; but, on the other hand, the pages of our Mathematical periodicals furnish numerous instances of complicated and lengthy co-ordinate discussions, the results of which are seen at a glance from the simplest principles of ordinary geometry. In all geometrical researches a quick perception of the proper system of investigation to be adopted ought to be especially the aim of the student:—*each method has its own peculiar advantages;* and that only ought to be adopted which conducts us most naturally to the required result. Both methods of investigation will thus assist in furthering the progress of Geometrical Science, and all idea of antagonism between the supporters of the ancient and modern practices will thus be rendered impossible; for it is as absurd to imagine that the modern geometrical methods will ultimately be abandoned for those of the Greeks, as it would be to suppose that the Astronomer will forsake his formulæ and return to graphical delineation, or the "rule of thumb." The change in the modes of conducting geometrical inquiries is without doubt both permanent and real; the works of Chasles and Mulcahy are undoubtedly but the *avant couriers* of a numerous and progressive race; nor will the expectations of those Lancashire Geometers soon be realised who hope to witness the re-establishment of the Ancient Analysis upon the ruins of the *Géométrie Supérieure.*

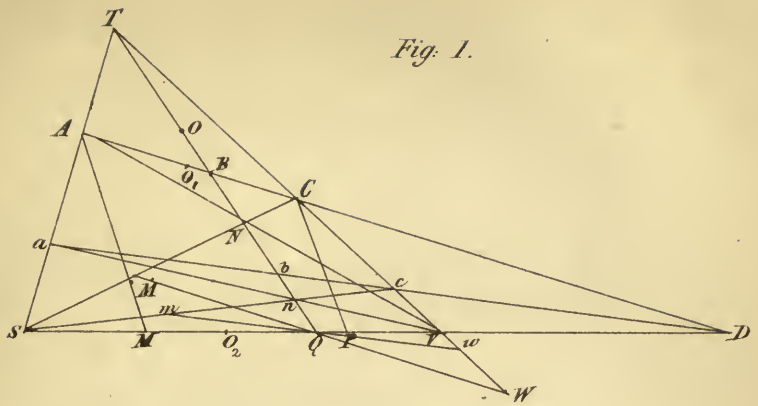

Fig. 1.

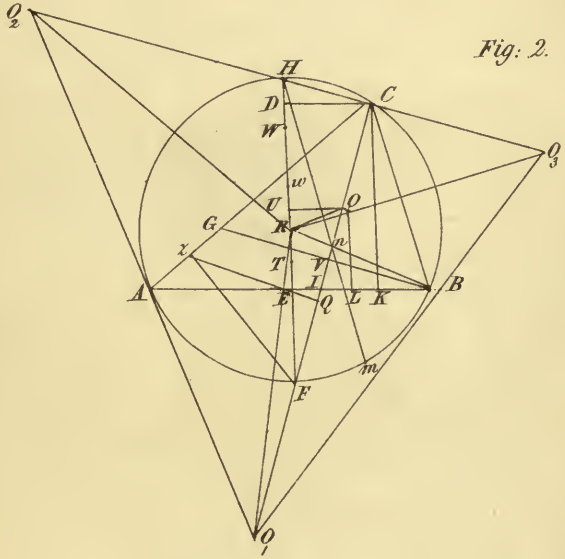

Fig. 2.

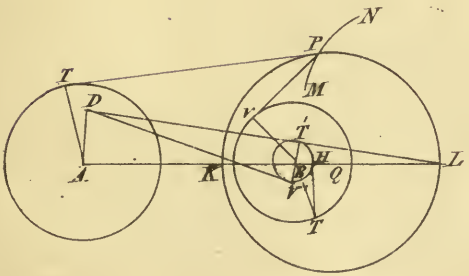

Fig. 3.

NATURAL HISTORY.

VI.—*Use of the Sulpho-Purpuric Acid, (or Red Sulphate of Indigo,) in the Dyeing of Worsted and Silk.*

By Mr. Edward Haeffely, of Mulhouse.

[*Read December 14th*, 1852.]

I take the liberty of drawing the attention of the Society to a new fact, demonstrated in the successful application on worsted and silk of the red sulphate of indigo, (the phenicine of Mr. Walter Crum.)

This chemical compound is produced by the action of sulphuric acid upon indigo, and by throwing the mixture thus obtained into a large quantity of water a few minutes after the contact. By this means a red-coloured precipitate is formed, which, when well and thoroughly washed on a filter, represents the red compound in question, a very different production from the blue sulphate of indigo in its composition, properties, and as regards the shades produced by it.

I have been able to produce with this red sulphate of indigo, shades superior in all respects to those obtained by the employment of the indigo extract, imitating the prussian blue, and likewise purple shades bearing an imitation of those produced by the use of logwood and cudbear, which shades, I should observe, cannot be produced from the commercial indigo "carmine;" I have been induced therefore to communicate the results of the experiments I have made in this matter, and at the same time I have the

honour of exhibiting for inspection some patterns, the results of the putting into operation of both processes, so that the difference between the two may be fairly estimated. I may be permitted to say that I have not the least doubt that after a careful examination of these patterns, every one will be inclined to give a preference to the blue and purple colours obtained by the use of the red sulphate, which has been introduced into commerce, and applied by dyers with success, in some dyeing establishments of the neighbouring county of York.

I will now enter into a few details respecting the chemical nature of these two sulphates. Upon an examination of the formulæ of the two chemical bodies referred to, it will be found that the ordinary indigo extract is, properly speaking, a hypo-sulphate of dehydrogenised indigo

$$= S^2 O^5 + N C^{16} H^4 O^2,$$

(The formula of the indigotine being—

$$N C^{16} H^5 O^2,)$$

whilst the red compound is a sulphate of indigotine—

$$S O^3 . H O + N C^{16} H^5 O^2.$$

Upon a comparison of these two formulæ, it will be remarked that in the case of the indigo extract, the indigo and the sulphuric acid have undergone remarkable alterations: the indigo having lost a portion of its hydrogen, and the sulphuric acid a portion of its oxygen,—and these two elements, hydrogen and oxygen, having united to form water. But in the case of the red sulphate, the indigo and the sulphuric acid have entered into combination *without* undergoing any change.

As in the composition of the red sulphate the colouring matter is "or appears" *unaltered*, I was induced to entertain the supposition that it might be beneficially used in dyeing, for obtaining solid blues directly, an operation which might probably replace with advantage the process of obtaining blues from vats.

A circumstance which is in favour of the possibility of fixing this colouring matter on fabrics in a state of indigotine is, that some organic substances (such as sulpho-vinic acid, sulpho-glyceric acid, and other sulpho-acids) possess the property of being decomposed and resolving themselves into their primitive constituents by a simple ebullition in water.

This red sulphate of indigo may be ranked in that type of organic bodies, where it figures under the name of *Sulpho-purpuric Acid.* As it ought to partake of the properties of the series of compounds mentioned, it should necessarily, on its ebullition in water, decompose itself into *free indigo* on one side, and into *free* sulphuric acid on the other. Consequently I presumed that by introducing fabrics into the vessel where the process was going on, and at the moment of the separation of the colouring matter, I could fix this colour upon the fabrics so introduced.

But the first experiment I made did not turn out to be satisfactory. Cotton remained untouched by the colour, whilst the worsted took off and successfully retained the colouring matter. I made three consecutive trials on the occasion; the first in a neutral bath, the second in an acid bath, and the third in an alkaline one; but in all the three cases, so far as the cotton was concerned, there was no successful result. Hence it appears that the cotton has no affinity for this indigo. But silk and worsted may be effectually dyed in the way I have indicated, if the bath be only kept acid.

As I have already observed, some of these patterns imitate the prussian blue, and those washed in soap or alkaline water resemble the purple produced from logwood and cudbear, which shades could not, up to the present time, be produced by the employment of indigo alone.

A question which it will now be worth while particularly to inquire into is this—whether the indigo appears *on these fabrics* as indigotine, or as sulpho-purpuric acid, or as a modification of this acid.

I incline to the opinion that it is a modification of indigotine, or of the acid colouring substance; for I found that this sulpho-purpuric acid, in contrariety to the opinion generally entertained, is an intense red-coloured compound WHEN DRY, and not an intense blue one.

Nevertheless, upon examining the patterns dyed with this *red compound*, it will be found that they *are blue on these fabrics*, and *not red;* and those patterns passed through alkali *are purple*,—an effect which is not produced by indigotine.

I have not yet completely solved this question, and for the present only take the liberty of calling attention to the new shades obtained by the employment, in the dyeing process, of this sulpho-purpuric acid, viz., the blue, imitating prussian blue, and the indigo purple, imitating the shades obtained by the use of logwood.

VII.—*On a Case of Poisoning by Sulphate of Protoxide of Iron.*

By Mr. F. Crace Calvert, Hon. Professor of Chemistry, Royal Manchester Institution.

[*Read January 25th*, 1853.]

As the recorded cases of poisoning by sulphate of protoxide of iron are rare, there being only two cases described in Christison and Taylor's valuable works, and a third which occurred about twelve months ago, I believe it may prove interesting to some of the members of our Society to have a case presented to their notice which I have recently examined; the more so as, owing to the kindness of Dr. Brown (the Lecturer on Medicine, and one of my colleagues at the Royal Medical School here,) I am enabled to give an anatomical description of the stomach and intestines, which has not hitherto been given in cases of poisoning with green copperas.

On Thursday, the 4th of December last, Mr. Girdleston, surgeon, at Shelton, brought me the stomach and intestines of John Hill, late of Bagnall, near Stoke, Staffordshire, who had died, he supposed, from the effects of some irritant poison; he had found all the organs of the deceased healthy, with the exception of the stomach and intestines, which were highly inflamed. Mr. Girdleston also stated that at about half-past nine o'clock on the morning of the 27th of November, the deceased had been seized with sickness and purging, which continued up to the period of his death, about nine o'clock the same evening.

The evidence at the inquest was adjourned until chemical research could be brought to bear upon it. I much regretted that the liver had not been removed, in addition to the stomach and intestines, and had determined to request the disinterment of the corpse, but having been enabled in my examination of the stomach and intestines to find copperas, I thought it unnecessary to exhume the body. I first removed the small amount of fluid which was found in the stomach; I then placed in another vessel the contents of the intestines, and to these I added respectively some washings obtained by cleansing these viscera with distilled water. These fluids being heated to ebullition, and the coagulum thus produced separated from the liquid, the precipitates were desiccated, and the fluids evaporated to dryness in an oil bath of 220° Fahr. These were examined for oxalic acid, oxalates, bi-chloride of mercury, salts of antimony, lead, copper, and barytes.

Having arrived at no results, but still believing death to be due to some irritant poison, I tested for salts of zinc, during which process I detected the presence of salts of iron, and having satisfied myself that an unusual quantity existed in the coagulum, and in the fluid separated therefrom, as well as in the tissues of the stomach and intestines, I then proceeded to determine the quantity of iron still remaining in the tissues, as well as in the fluid and solid matters which I had obtained from them. I say remaining quantities; for the amount I extracted could be only a small proportion of that taken by the deceased, as he had vomited nearly constantly for twelve hours, and been also purged.

I found by experiment that it was impossible to extract all the oxide of iron, by simply carbonizing the matters, and treating them with aqua regia, evaporating to dryness, and washing; but it was essential that the carbon should be perfectly removed by calcination, before the whole of the iron could be removed.

Having to contend with phosphates which would have rendered the determination of the iron in the state of per-oxide of iron very tedious and difficult, I treated the calcined residuum with pure hydro-chloric acid, evaporated with care to a syrup, added water, and filtered; the liquors were then reduced to the state of proto-chloride of iron by means of pure zinc, and the amount of iron they contained determined by Marguerite's test (per-manganate of potash). The following results were obtained:—

	Grs.
6½ oz. of the Intestines yielded SO^3FeO	1·054
5½ oz. of the Stomach yielded SO^3FeO	0·324
Of portions of the Stomach and Intestines previously treated for other poisons.....	1·256
The Coagulum obtained by boiling the fluids of the Stomach	0·660
Contents of the Stomach separated from the Coagulum and evaporated to dryness, and insoluble in Alcohol.....	0·526
In the above, but soluble in Alcohol	0·324
Liquid obtained by washing Intestines	0·993
Fluid from the Intestines	0·526
Total amount of Copperas, or the Sulphate of Protoxide of Iron.....	5·663

I also found an unusual quantity of sulphuric acid or sulphates in the different fluids.

An interesting fact is, that although nine days had elapsed between the death of John Hill and the day following that on which the intestines were placed in my hands, the patches or spots on the intestines still preserved an acid reaction, which was manifested on a slip of blue litmus paper being applied to them.

I have great pleasure in publishing here an extract of the anatomical appearance of the intestines and stomach, as described by Dr. Henry Brown:—

"*The stomach*, which had been previously laid open, pre-
"sented nothing worthy of remark, excepting a trace of
"arborescent vascularity in the sub-mucous tissue. The
"mucous membrane could not be easily stripped off.

"*The intestines* externally presented no unusual appear-
"ances except in five places, all of which were confined to
"the jejunum; in each of them the uniform purplish red hue
"of the peritoneal covering was changed to a dirty opaque
"white, studded with minute flocculent-looking brownish
"spots. The form of each was oval, with the exception of
"the second in order from the stomach, which had two
"pointed extremities. They equalled in size a half-crown
"piece, some more, some less, and were all situated on the
"free border of the intestines, none reaching around or
"across the entire circumference. The margins of the spots
"were very distinct, with the exception of the last; and at
"first sight the spots seem to have been produced by a fold
"of the intestine having rested against the dry surface of the
"glass jar in which they had been kept, by which the blood
"had been pressed out from them. On extending the peri-
"toneal coat, however, it was evident that such was not the
"case, for each spot was found to be encircled by two distinct
"rings of different colours; the first was very slight and red,
"and the second, which was a quarter of an inch in breadth,
"was of an ivory white colour. The white colour was shaded
"off evenly, but abruptly, towards the uniform general redness
"of the parts not marked; the shading did not occupy more
"than one-eighth of an inch.

"*Internally*, the folds of the mucous membrane (valvula
"conniventis) were every where of a deep purplish red colour,
"excepting in the parts corresponding to the external mark-
"ings, from which the colour had been discharged. The
"mucous membrane in consequence, over a space equal to the
"whole of the external marks, was whitish, and the shading
"off was so gradual as to extend at least a quarter of an inch

"beyond the external white zone. There was no thickening "of any of the coats of the intestines in the places thus "marked, neither did they appear to have lost any of their "cohesion and firmness; the mucous membrane did not peel "off more readily than elsewhere.

"The contents of the intestines consisted of a thin, reddish "brown gelatinous mucus, without any hardened fœces."

Dr. Brown adds,—"From the above facts, I believe that "the appearance could not have been caused by mechanical "pressure and drying after death, neither do I know of any "other post-mortem cause capable of producing them. The "appearances have all the characteristics of extreme vital "irritation (without actual corrosion) in its very first stage— "stages which have been suddenly arrested, and stereotyped "as it were, by death. Four fully-grown tape-worms were "found, with their heads, and have been preserved."

VIII.—*On Supplementary Curves.*

By Robert Finlay, B.A. of Trin. Coll., Dublin, Professor of Mathematics in Manchester New College.

[*Read March 8th*, 1853.]

The following paper contains, it is hoped, some contributions to the Theory of Imaginaries in Geometry. It was originally intended to include only such points in that theory as appeared to me to be new; but, having proceeded some length in drawing up the paper, it occurred to me that its utility might be increased by including such an outline of what has already been published on the subject as would make the paper intelligible in itself without perpetual references to other sources of information. Accordingly, the first section contains some matter which is not absolutely new; the principal definitions having been given by M. Poncelet, in his splendid work "*On the Projective Properties of Figures*," published in 1822, and several of the preliminary theorems having been published in the *Mathematician*, early in 1846, in some papers of mine "*On the Application of Algebra to the Modern Geometry*."

The first idea of writing the paper originated in the perusal of a long note at the end of Mr. Salmon's new book "*On the Higher Plane Curves*." In this note he has combated the two principal theories of imaginaries, as proposed respectively by M. Poncelet, and the late Mr. Gregory, of Cambridge. An able defence of Gregory's theory has just been published in No. XXX. of the *Cambridge and Dublin Mathematical Journal*. In this paper I have confined myself to Poncelet's

theory exclusively, but my object is not so much to defend this theory as to illustrate and extend it.

Section I.—Preliminary Propositions.

1.

If the circle $x^2 + y^2 = a^2$ be cut by a straight line $x = c$, the ordinates of the points of intersection will evidently be

$$+ \sqrt{(a^2 - c^2)} \text{ and } - \sqrt{(a^2 - c^2)},$$

which are both imaginary when c is greater than the radius a. Thus we see that *any straight line in the plane of the circle, and at a distance from its centre greater than the radius, cuts the circle in two imaginary points.* Now it has been proposed by M. Poncelet, (*Traité des Propriétés Projectives des Figures*, p. 29.) that the real points

$$x = c,\ y = \sqrt{(c^2 - a^2)} \text{ and } x = c,\ y = -\sqrt{(c^2 - a^2)},$$

obtained by changing the sign of the quantity under the radical in the imaginary expressions given above, should be taken as the representatives of the imaginary points in question. Again, since $2\sqrt{(a^2 - c^2)}$ may be considered as the imaginary chord which the circle intercepts on the given line, M. Poncelet has proposed that the real expression $2\sqrt{(c^2 - a^2)}$ should be considered as the *ideal chord* intercepted by the circle $x^2 + y^2 = a^2$ on the straight line $x = c$. He has also applied the term *ideal chord* to the indefinite straight line $x = c$, when its intersections with the circle are imaginary: hence any straight line in the plane of a circle may be considered as the chord of the circle; but, for the sake of distinction, it is called a *real* chord when it cuts the circle in two real points, and an *ideal* chord when its intersections with the circle are imaginary, or when it lies wholly without the circle.

These principles being admitted, if an arbitrary series of straight lines be drawn, each of which cuts the circle in two imaginary points, the corresponding real points will not in

general lie upon any particular locus; but when the lines succeed one another according to any given law, the representatives of the imaginary points in which they meet the circle will lie upon a regular curve, which may be considered as the locus of the imaginary points in which the circle is cut by any straight line subject to that law. Now since what has been said of the circle may readily be extended to any given curve, the following problem is naturally suggested:—

Any plane curve being given, to find the locus of the imaginary points in which it is cut by a series of straight lines drawn in the plane of the curve so as to succeed one another according to any given law.

In the present state of algebraical science there is little hope of obtaining a solution to this problem, except in particular cases. In this paper I shall confine myself to the two simplest cases, viz.,—1st. The case in which the system of secants is parallel to a given straight line;—2nd. That in which all the secants pass through the same point: and I propose to show, by a few examples, that the locus in question is intimately connected with the given curve in many important properties.

But before proceeding to the solutions of these problems it may be expedient to establish some general theorems, by means of which the subsequent investigations will be greatly simplified and abridged.

II.

Let $u = Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + 1 = 0$ .....(1)
be the equation to any conic section,

$$v = \alpha y + \beta x + 1 = 0 \text{ .....(2)},$$

$$v' = \alpha' y + \beta' x + 1 = 0 \text{ .....(3)},$$

the equations of two straight lines; then the equation

$$u_1 = u + kvv' = 0 \text{ .....(4)},$$

where k is an arbitrary constant, will represent a system of conic sections passing through the four points in which the

curve u is cut by the straight lines v and v'. For, since any values of x and y which satisfy the simultaneous equations (1) and (2) will also satisfy equation (4), it follows that the curve u_1 must pass through the two points in which the curve u is cut by the straight line v; and in a similar manner it can be shown that the curve u_1 passes through the intersections of u and v'.

(*a*.) When the straight line v is without the curve u, the points in which it intersects that curve will be imaginary; and since the curve u_1 passes through these points, it follows that in this case v will be an ideal common secant of u and u_1. But when the straight line v cuts the curve u in two real points, the curve u_1 will pass through these points, and v will be a real common secant of u and u_1.

(*b*.) When $\alpha' = 0$ and $\beta' = 0$, the straight line v' passes to infinity, because the points in which it meets the axes of x and y are at infinity. In this case we have $v' = 1$, and equation (4) becomes

$$u_2 = u + kv = 0 \ldots\ldots\ldots\ldots(5).$$

Hence we see that this equation represents a system of conic sections having with the curve u a common secant at infinity. When the curve u is an ellipse, this secant at infinity must evidently be ideal.

Since the terms containing the squares and product of x and y are the same in equations (1) and (5), the curves u and u_2 are evidently similar and similarly placed. Hence any two curves of the second degree which are similar and similarly placed have a common secant at infinity.

(*c*.) If $\alpha' = \alpha$ and $\beta' = \beta$, the straight lines v and v' will coincide, and the four points of intersection of the curves u and u_1 will coalesce into two points of contact. In this case equation (4) becomes

$$u_3 = u + kv^2 = 0 \ldots\ldots\ldots\ldots(6),$$

which therefore represents a conic section having a double contact with the curve u, the equation to the chord of contact

being $v = 0$. When the straight line v is without the curve u, the two points of contact are imaginary, and the chord of contact is ideal.

(*d.*) When $\alpha = 0$ and $\beta = 0$, the straight line v passes to infinity, and equation (6) becomes

$$u_4 = u + k = 0 \ldots\ldots\ldots\ldots(7).$$

Now since this differs from equation (1) only in its absolute term, it is evident that the curves u and u_4 are concentric, similar, and similarly placed; and thus we see that any two curves of the second degree which are concentric, similar, and similarly placed, have a double contact at infinity. From this it follows that any two concentric circles have a double contact at infinity. In this case, as well as that of two similar and concentric ellipses, the points of contact must evidently be imaginary, and the chord of contact ideal.

(*e.*) When the quadratic function u can be resolved into two factors v_1 and v_2 of the first degree, equation (6) becomes

$$u_5 = v_1 v_2 + k v^2 = 0 \ldots\ldots\ldots\ldots(8).$$

In this case the conic section u breaks up into two straight lines v_1 and v_2, and the curve u_5 touches these lines at the points in which they are cut by the straight line v. Hence it is evident that the point of intersection of v_1 and v_2 is the pole of the straight line v in relation to the curve u_5. Now when the lines v_1 and v_2 are imaginary, their point of intersection is real, and continues to be the pole of the straight line v; but the points in which v_1 and v_2 touch the curve u_5 are imaginary, and the chord of contact v is ideal.

III.

The theorems given in the last number relative to the conic sections may readily be generalized. Thus, if $u = 0$ be a curve of the nth degree, and if $v = 0$ and $v' = 0$ be two curves of the mth degree, where m is not greater than $\frac{1}{2} n$, then $u + k v v' = 0$ will represent a system of curves of the

nth degree, passing through the points in which the curves v and v' intersect the curve u. Again, when the curves v and v' coincide, the $2mn$ points of intersection unite into mn points of contact; so that the equation $u + kv^2 = 0$ represents a curve of the nth degree touching the curve u at mn points which lie on the curve of contact v. It is evident also that all this reasoning holds good when any of the curves u, v, v' breaks up into a system of straight lines.

IV.

Let $u = Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + F = 0$ .....(1), and $u' = A'y^2 + 2B'xy + C'x^2 + 2D'y + 2E'x + F' = 0$ .....(2), represent any two conic sections; then, if k denote a given constant, the equation

$$u_1 = u + k u' = 0 \text{ .....(3)}$$

will evidently represent a conic section passing through the four points of intersection of the curves u and u'. Putting $A + kA' = A_1$, $B + kB' = B_1$, &c., equation (3) may be written in the form

$$A_1y^2 + 2B_1xy + C_1x^2 + 2D_1y + 2E_1x + F_1 = 0 \text{ .....(4).}$$

Now if k be so assumed that the first member of this equation can be resolved into two factors of the first degree, the curve u_1 will break up into two straight lines, which will be conjugate common secants of the curves (1) and (2). In this case, let x_1 and y_1 be the co-ordinates of the point of intersection of the two lines in question; then, by transferring the origin of co-ordinates to this point, equation (4) becomes

$$A_1y^2 + 2B_1xy + C_1x^2 + 2D_2y + 2E_2x + F_2 = 0 \text{ .....(5);}$$

where, for the sake of brevity, we assume

$$\left.\begin{aligned} D_2 &= A_1y_1 + B_1x_1 + D_1 \\ E_2 &= B_1y_1 + C_1x_1 + E_1 \end{aligned}\right\} \text{.....(6),}$$

$$F_2 = A_1y_1^2 + 2B_1x_1y_1 + C_1x_1^2 + 2D_1y_1 + 2E_1x_1 + F_1 \text{ .....(7).}$$

Because the two straight lines represented by equation (5) pass through the new origin, we must evidently have

$$D_2 = 0,\ E_2 = 0,\ F = 0;$$

and by eliminating x_1 and y_1 from these three equations we shall have

$$A_1E_1^2+C_1D_1^2+F_1B_1^2-2B_1D_1E_1-A_1C_1F_1=0 \quad \ldots\ldots(8),$$

which is an equation of the third degree with respect to k, since A_1, B_1, C_1, &c., are linear functions of k. Now since every equation of the third degree has at least one real root, it follows that one of the values of k deduced from equation (8) must be real; and if this value be substituted in equations (6) we shall obtain the corresponding values of x_1 and y_1, which will also be real, since equations (6) are of the first degree. Hence we see that *any two conic sections* (1) *and* (2) *described in the same plane have at least one system of conjugate common secants, the point of intersection of which is necessarily real, although the secants themselves may be imaginary.*

V.

If a straight line AP be cut by a given curve of the nth degree in the points Q_1, Q_2, Q_3.....Q_n, it is required to express the ratio

$$PQ_1 \cdot PQ_2 \cdot PQ_3 \ldots\ldots PQ_n : AQ_1 \cdot AQ_2 \cdot AQ_3 \ldots\ldots AQ_n,$$

which is compounded of the ratios of the segments of AP, in terms of the co-ordinates of P referred to any rectangular axes passing through A.

Let x', y' be the co-ordinates of P, and put $AP=r$, $AQ_1=\rho_1$, $AQ_2=\rho_2$, $AQ_3=\rho_3$ .....$AQ_n=\rho_n$; then, if we adopt the notation

$$(PQ_n)=PQ_1 \cdot PQ_2 \cdot PQ_3 \ldots\ldots PQ_n,$$

we shall have $\dfrac{(PQ_n)}{(AQ_n)}=\dfrac{(r-\rho_1)(r-\rho_2)(r-\rho_3)\ldots\ldots(r-\rho_n)}{\rho_1 \cdot \rho_2 \cdot \rho_3 \ldots\ldots \rho_n}$;

and when n is even this reduces to

$$\frac{(PQ_n)}{(AQ_n)}=1-\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}+\&c.\right)r+\left(\frac{1}{\rho_1\rho_2}+\frac{1}{\rho_1\rho_3}+\frac{1}{\rho_2\rho_3}+\&c.\right)r^2 - \&c. \ldots\ldots\ldots\ldots(1).$$

Let $u=0$ be the equation of the given curve; then

$u = 1 + f_1(x, y) + f_2(x, y) + f_3(x, y) \ldots + f_n(x\,y) = 0 \ldots\ldots (2)$, where $f_m(x, y)$ denotes a complete homogeneous function of x and y of the mth degree, such as

$$A\,x^m + B\,x^{m-1}y + C\,x^{m-2}y^2 + \&c.;$$

then if ρ denote the radius vector of the curve u, θ and ϕ the cosines of the angles which ρ makes with the axes of x and y, we shall have

$$x = \rho\,\theta,\ y = \rho\,\phi;$$

and by substituting these values of x and y in equation (2) we obtain

$1 + r \cdot f_1(\theta, \phi) + r^2 \cdot f_2(\theta, \phi) + r^3 \cdot f_3(\theta, \phi) \ldots + r^n \cdot f_n(\theta, \phi) = 0$, which is the polar equation to the given curve. Now since $\rho_1, \rho_2, \rho_3, \ldots\ldots \rho_n$ are the roots of this equation, we obtain, by the theory of equations,

$$\frac{1}{\rho_1} + \frac{1}{\rho_2} + \frac{1}{\rho_3} + \&c. = -f_1(\theta, \phi),$$

$$\frac{1}{\rho_1\rho_2} + \frac{1}{\rho_1\rho_3} + \frac{1}{\rho_2\rho_3} + \&c. = f_2(\theta, \phi), \&c.;$$

hence, by substituting these expressions in equation (1), we get

$(PQ_n) : (AQ_n) = 1 + r \cdot f_1(\theta, \phi) + r^2 \cdot f_2(\theta, \phi) \ldots + r^n \cdot f_n(\theta, \phi)$; and since $r\,\theta = x'$ and $r\,\phi = y'$, this equation can be written in the form

$(PQ_n) : (AQ_n) = 1 + f_1(x', y') + f_2(x', y') \ldots + f_n(x', y') = u'$, where u' denotes the same function of x' and y' as u is of x and y.

When n is odd it may be demonstrated in the same manner that $(PQ_n) : (AQ_n) = -u'$; hence, generally, we have

$$\frac{PQ_1 \cdot PQ_2 \cdot PQ_3 \ldots\ldots PQ_n}{AQ_1 \cdot AQ_2 \cdot AQ_3 \ldots\ldots AQ_n} = \pm u' \ldots\ldots\ldots\ldots (3),$$

where the upper or lower sign must be taken according as n is even or odd.

(*a*.) When the proposed equation is of the first degree, the demonstration still holds good, and equation (3) becomes

$$PQ_1 : AQ_1 = -u'.$$

In this case, if PM and AN be drawn perpendicular to the given line u, the triangles AQ_1N and PQ_1M will evidently be similar, and we shall have

$$PQ_1 : AQ_1 = PM : AN;$$

in virtue of which the preceding equation becomes

$$PM : AN = -u' \ldots\ldots\ldots\ldots(4).$$

(*b*.) It is evident that the demonstration given above will hold good when the proposed equation $u = 0$ is resolvable into factors. Let it be resolvable into n factors of the first degree, in which case it will represent a system of n straight lines. Let PM_1, PM_2, PM_3..... PM_n and AN_1, AN_2, AN_3, ... AN_n be the perpendiculars drawn from P and A respectively to these lines; then, by similar triangles,

$$PQ_1 : AQ_1 = PM_1 : AN_1,\ PQ_2 : AQ_2 = PM_2 : AN_2, \text{ \&c.},$$

and therefore equation (3) may be written in the form

$$\frac{PM_1 \cdot PM_2 \cdot PM_3 \ldots\ldots PM_n}{AN_1 \cdot AN_2 \cdot AN_3 \ldots\ldots AN_n} = \pm u' \ldots\ldots\ldots\ldots(5).$$

(*c*.) The last equation fails when each of the n straight lines represented by the equation $u = 0$ passes through the point A; since, in that case, each of the perpendiculars AN_1, AN_2, &c. is zero. In this case equation (2) takes the form

$$u = A_1y^n + A_2y^{n-1}x + A_3y^{n-2}x^2 \ldots\ldots + A_nx^n = 0 \ldots\ldots\ldots\ldots(6),$$

and if we assume $y = mx$ this becomes

$$A_1m^n + A_2m^{n-1} + A_3m^{n-2} \ldots\ldots + A_n = 0 \ldots\ldots\ldots\ldots(7).$$

Now if m_1, m_2, m_3, ... m_n denote the roots of this equation, these will evidently be the direction indices of the system of straight lines represented by equation (6), so that the equations of these lines will be

$$y = m_1x,\ y = m_2x, \ldots\ldots y = m_nx \ldots\ldots\ldots\ldots(8).$$

Let x' and y' be the co-ordinates of P, then, by the theory of the straight line, we shall have

$$PM_1 = \frac{y' - m_1 x'}{\sqrt{(1+m_1^2)}},\ PM_2 = \frac{y' - m_2 x'}{\sqrt{(1+m_2^2)}},\ \&c.,$$

$$\therefore PM_1 . PM_2 \ldots PM_n = \frac{(y' - m_1 x')\,(y' - m_2 x') \ldots (y' - m_n x')}{\sqrt{\{(1+m_1^2)\,(1+m_2^2) \ldots (1+m_n^2)\}}}$$

$$= \frac{u'}{A_1 \sqrt{\{(1+m_1^2)\,(1+m_2^2)\,(1+m_n^2)\}}} \ldots (9).$$

This equation shows that the function u' has a fixed ratio to the continued product of the perpendiculars PM_1, PM_2, PM_3 ..... PM_n. Denoting this ratio by M, equation (9) gives

$$M^2 = A_1^2 (1+m_1^2)\,(1+m_2^2)\,(1+m_3^2) \ldots\ldots (1+m_n^2) \ldots\ldots\ldots (10);$$

or, by performing the multiplication

$$M^2 = A_1^2 \{1 + (m_1^2 + m_2^2 + m_3^2 + \&c.) + (m_1^2 m_2^2 + m_1^2 m_3^2 + m_2^2 m_3^2 + \&c.) + (m_1^2 m_2^2 m_3^2 + \&c.) + \&c.\} \ldots\ldots\ldots\ldots (11).$$

The values of these symmetrical functions of the roots m_1, m_2, &c. may be very easily obtained by constructing the equation whose roots are m_1^2, m_2^2, m_3^2, &c. For the sake of simplicity let us consider the case of $n = 5$; then equation (7) becomes

$$A_1 m^5 + A_2 m^4 + A_3 m^3 + A_4 m^2 + A_5 m + A_6 = 0.$$

If we assume $m^2 = z$ this becomes

$$z^2 (A_1 z^2 + A_3 z + A_5) + A_2 z^2 + A_4 z + A_6 = 0;$$

hence, by clearing the radical, and arranging according to the powers of z, we get

$$A_1^2 z^5 + (2A_1 A_3 - A_2^2) z^4 + (A_3^2 + 2A_1 A_5 - 2A_2 A_4) z^3 + (2A_3 A_5 - 2A_2 A_6 - A_4^2) z^2 + (A_5^2 - 2A_4 A_6) z - A_6^2 = 0.$$

Now since m_1^2, m_2^2, m_3^2, &c. are the roots of this equation, we shall have

$$m_1^2 + m_2^2 + \&c. = (A_2^2 - 2A_1 A_3) : A_1^2,$$

$$m_1^2 m_2^2 + m_1^2 m_3^2 + \&c. = (A_3^2 - 2A_2 A_4 + 2A_1 A_5) : A_1^2,$$

$$m_1^2 m_2^2 m_3^2 + \&c. = (A_4^2 + 2A_2 A_6 - 2A_3 A_5) : A_1^2, \&c. \&c.$$

and in virtue of these equation (11) becomes

$$M^2 = A_1^2 + A_2^2 - 2A_1A_3 + A_3^2 - 2A_2A_4 + 2A_1A_5 + A_4^2$$
$$+ 2A_2A_6 - 2A_3A_5 + A_5^2 - 2A_4A_6 + A_6^2,$$

and this may evidently be written in the form

$$M^2 = (A_1 - A_3 + A_5)^2 + (A_2 - A_4 + A_6)^2 \ldots\ldots\ldots(12).$$

In the general case we should evidently arrive at a similar result, and hence equation (9) gives

$$u' = M \times PM_1 . PM_2 . PM_3 \ldots\ldots PM_n \ldots\ldots\ldots\ldots(13),$$

where $M^2 = (A_1 - A_2 + A_3 - \&c.)^2 + (A_2 - A_4 + A_6 - \&c.)^2 \ldots(14).$

(*d.*) The formulas demonstrated in this number are of great importance in reducing geometrical expressions to algebraic form, and the converse. Let us consider, for instance, the equation

$$u_1 = u + kvv' = 0, \text{ (II, 4.)}$$

Let AP be a straight line drawn from the origin A to any point P in the curve u_1, and let this line meet the conic section u in the points Q_1 and Q_2, and the straight lines v and v' in R_1 and R_2 respectively; then, by equations (3) and (4),

$$u = \frac{PQ_1 . PQ_2}{AQ_1 . AQ_2}, \quad v = -\frac{PR_1}{AR_1}, \quad v' = -\frac{PR_2}{AR_2};$$

$$\therefore u_1 = \frac{PQ_1 . PQ_2}{AQ_1 . AQ_2} + k\frac{PR_1 . PR_2}{AR_1 . AR_2} = 0.$$

Hence we see that the curve u_1 may be considered as the locus of a point P, such that if a straight line be drawn from it to a fixed point A, meeting the curve u in Q_1 and Q_2, and the straight lines v and v' in R_1 and R_2, the compound ratio $PQ_1 . PQ_2 : AQ_1 . AQ_2$ shall have to $PR_1 . PR_2 : AR_1 . AR_2$ a fixed ratio—k.

Section II.—Of Curves which are supplementary in relation to a given Straight Line.

VI.

A curve of the second degree being given, to find the locus of the imaginary points in which it is cut by a system of straight lines parallel to a given line.

If the given line be taken as the axis of y, the equation of the given curve will be of the form

$$Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + F = 0.$$

By solving this with respect to y, we get

$$Ay = -(Bx+D) \pm \sqrt{\{(Bx+D)^2 - A(Cx^2+2Ex+F)\}} \ldots (1),$$

and by changing the algebraic sign of the quantity under the radical sign in this expression, we obtain

$$Ay = -(Bx+D) + \sqrt{\{A(Cx^2+2Ex+F) - (Bx+D)^2\}} \ldots (2),$$

which is the equation of the required locus.

(*a*.) Since every value of x which gives real values of y in equation (2) will give imaginary values of y in equation (1), it is evident that the original curve (1) is the locus of the imaginary points in which the curve (2) is cut by a series of straight lines parallel to the axis of y. Hence we see that *any straight line, parallel to the axis of* y, *will meet one of the curves in two real points, which may also be considered as imaginary points on the other curve.* On account of this remarkable relation, the curves (1) and (2) have been called *supplementary conics in relation to the axis of* y. But since the property does not hold good with respect to straight lines drawn in any other direction, the curves (1) and (2) are not supplementary, except in relation to the system of parallel straight lines in question.

(*b*.) Similarly, any two curves A and B may be said to be *supplementary in relation to a given straight line*, when any straight line parallel to the given one meets the curve A in

p real and q imaginary points, while the same straight line meets the curve B in q real and p imaginary points.

(*c.*) It is evident from equations (1) and (2) that the diameter

$$Ay + Bx + D = 0 \ldots\ldots\ldots (3),$$

which bisects chords parallel to the axis of y, is common to the curves (1) and (2); hence, *if the two conics are supplementary in relation to a given straight line, the diameters of the two curves which bisect chords parallel to that line are coincident in direction.*

(*d.*) Equations (1) and (2) may evidently be written in the form

$$(Ay + Bx + D)^2 = (Bx + D)^2 - A(Cx^2 + 2Ex + F) \ldots (4),$$

$$(Ay + Bx + D)^2 = -(Bx + D)^2 + A(Cx^2 + 2Ex + F) \ldots (5),$$

from which we see (II, 8) that the supplementary conics (1) and (2) touch the two straight lines represented by the equation

$$(B^2 - AC)x^2 + 2(BD - AE)x + D^2 - AF = 0 \ldots\ldots (6)$$

at the points in which these lines are cut by the common diameter (3).

When the given curve is a parabola, we have $B^2 - AC = 0$; hence, in this case, equation (6) represents only one straight line, which touches each of the supplementary conics at the point in which it is cut by the common diameter (3).

(*e.*) From equations (4) and (5) we obtain by addition

$$(Ay + Bx + D)^2 = 0,$$

hence (II, *c*) the curves (4) and (5) have a double contact, the straight line (3) being the chord of contact. Thus we see that *two conic sections which are supplementary in relation to a given straight line have a double contact, the chord of contact being the diameter of each curve which bisects chords parallel to the given line.*

(*f.*) If equation (5) be denoted by

$$A'y^2 + 2B'xy + C'x^2 + 2D'y + 2E'x + F' = 0,$$

we shall have $A' = A^2$, $B' = AB$, $C' = 2B^2 - AC$,

$$\therefore B'^2 - A'C' = -A^2(B^2 - AC);$$

hence, *if the original curve be an ellipe the supplementary curve will be an hyperbola, but if the original curve be a parabola the supplementary one will also be a parabola.*

(*g*.) If any straight line be drawn through the origin A, meeting the curve (4) in a real point P (x, y), the straight line (3) in a point Q, and the two straight lines (6) in R_1 and R_2, we shall have (V, 3)

$$PQ : AQ = -(Ay + Bx + D) : D$$

$$PR_1 . PR_2 : AR_1 . AR_2 = \{(B^2 - AC)x^2 + 2(BD - AE)x + D^2 - AF\} : (D^2 - AF)$$

and in virtue of these equation (4) becomes

$$D^2\left(\frac{PQ}{AQ}\right)^2 = (D^2 - AF)\frac{PR_1 . PR_2}{AR_1 . AR_2} \quad \ldots\ldots\ldots(7).$$

If the same line meet the curve (5) in a real point P, we shall have

$$D^2\left(\frac{PQ}{AQ}\right)^2 = (AF - D^2)\frac{PR_1 . PR_2}{AR_1 . AR_2} \quad \ldots\ldots\ldots(8).$$

Hence we see that each of the supplementary curves (4) and (5) may be considered as the locus of a point P, such that $\frac{PR_1 . PR_2}{AR_1 . AR_2}$ has a fixed ratio to $\left(\frac{PQ}{AQ}\right)^2$; the algebraic sign of this ratio being different for the two curves, but its absolute magnitude being the same for both.

(*h*.) Let it be required to find the locus of a point P, such that if a straight line be drawn from it to a fixed point A, meeting the given straight line (3) in Q, and the two parallel straight lines (6) in R_1 and R_2, then $\frac{PR_1 . PR_2}{AR_1 . AR_2}$ shall have a given ratio to $\left(\frac{PQ}{AQ}\right)^2$.

To obtain the most general solution of this question, it would seem that the locus must include not only all the points between the straight lines (6) which satisfy the proposed condition, but also all points external to these lines on either side of them which satisfy the condition; and in a geometrical point of view the exterior and interior points in question seem to have perfectly equal claims to be considered as points of the locus. Now it is evident from what has been advanced above (*g*), that, when the given ratio is considered as a positive quantity, the equation to the required locus is (4), which represents the internal points; but when the ratio is considered as negative, the equation to the required locus is (5), which represents the external points. Thus we see that neither of the equations will represent the whole locus of external and internal points, unless we include the imaginary values of the variables; but that, with this assumption, either of the equations will represent the entire locus. Thus we have a remarkable instance, in which the science of algebra seems to be at fault, in point of generality, as compared with the kindred science of geometry; and it is not possible to remedy the defect except by admitting imaginary values of the algebraic symbols. This seems to afford a strong argument for considering the two supplementary curves (4) and (5) as branches of the same general curve; but I must admit that the authority even of CHASLES himself is opposed to this view of the subject.*

(*i.*) If the direction of the straight lines (6) be supposed to change, while the curve (4) remains invariable, the magnitude and position of the curve (5) will be changed; and conversely, if the straight lines (6 change their direction, while the curve (5) remains unchanged, the magnitude and position of the curve (4) will vary. In fact, we have seen (*g*) that the two supplementary conics (4) and (5) can be viewed as intimately related to the three straight lines (3) and (6), and of course

* See his *History of Geometry*, Note XXVI., page 396 of the German edition.

one or both of the conics may vary with any variation in the fundamental data. This consideration may perhaps remove Mr. Salmon's objection to this theory, which he has founded on the fact that any conic section has an infinite number of supplementary conics.

(*k*.) *If a system of conic sections have an ideal common secant, it will be a real common secant of the system of conics which is supplementary to the given one in relation to any straight line parallel to the common secant.* For, since every curve of the given system cuts the ideal chord in the same two imaginary points, these will evidently be real points on every curve of the supplementary system.

VII.

If two conic sections have a double contact, and if their supplementary conics be taken in relation to the chord of contact, the supplementary conics will have a double contact at the same points as the first two conics; so that, if the chord of contact be real for the one system it will be ideal for the other.

Let the axis of y be parallel to the chord of contact, then if the equation to one of the conics be

$$Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + F = 0 \ldots\ldots(1),$$

the equation of the other conic will be (II, *c*)

$$Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + F = m(b - x)^2 \ldots(2),$$

where $b - x = 0$ denotes the chord of contact. Now from equation (2) we readily obtain

$$Ay = -(Bx + D)$$
$$\pm\sqrt{\{(Bx + D)^2 - A(Cx^2 + 2Ex + F) + Am(b - x)^2\}},$$

from which it is evident (VI, *a*) that the equation of the conic supplementary to the curve (2) will be

$$(Ay + Bx + D)^2 = -(Bx + D)^2 + A(Cx^2 + 2Ex + F) - Am(b - x)^2 \ldots\ldots\ldots\ldots(3).$$

The equation of the conic supplementary to the curve (1) may be found from the last equation by taking $m = 0$, which gives

$$(Ay + Bx + D)^2 = -(Bx + D)^2 + A(Cx^2 + 2Ex + F) \ldots (4);$$

and it is evident (II, *c*) that the curves (3) and (4) have a double contact, the chord of contact being $b - x = 0$.

VIII.

To find the curve which is supplementary to any given curve of the third degree in relation to a straight line parallel to an asymptote.

If the given straight line be taken as the axis of y, the equation to the given curve will be of the form

$$By^2x + 2Cyx^2 + Dx^3$$
$$+ Ey^2 + 2Fxy + Gx^2 + 2Hy + Kx + L = 0.$$

By solving this equation for y, we obtain

$$(1) \ldots\ldots\ldots\ldots (Bx + E)y = -(Cx^2 + Fx + H)$$
$$\pm\sqrt{\{(Cx^2 + Fx + H)^2 - (Bx + E)(Dx^3 + Gx^2 + Kx + L)\}},$$

and therefore the equation to the required curve is

$$(2) \ldots\ldots\ldots\ldots (Bx + E)y = -(Cx^2 + Fx + H)$$
$$\pm\sqrt{\{-(Cx^2 + Fx + H)^2 + (Bx + E)(Dx^3 + Gx^2 + Kx + L)\}}.$$

(*a*) It is evident from the forms of these two equations that the hyperbola

$$(Bx + E)y = -(Cx^2 + Fx + H) \ldots\ldots\ldots\ldots (3)$$

bisects every chord of either curve which is parallel to the axis of y. Hence we see that *the curvilinear diameter which bisects chords parallel to the axis of* y *is common to the two supplementary curves.*

(*b*) By clearing the radicals from equations (1) and (2), we get

$$\{(Bx + E)y + Cx^3 + Fx + H\}^2 = (Cx^3 + Fx + H)^2 - (Bx + E)(Dx^3 + Gx^2 + Kx + L) \ldots\ldots\ldots(4),$$

$$\{(Bx + E)y + Cx^3 + Fx + H\}^2 = -(Cx^3 + Fx + H)^2 + (Bx + E)(Dx^3 + Gx^2 + Kx + L) \ldots\ldots\ldots(5);$$

from which we see (III) that each of the supplementary curves touches the four straight lines represented by the equation

$$(C^2 - BD)x^4 + (2CF - BG - DE)x^3 + (F^2 + 2CH - BK - GE)x^2 + (2FH - BL - KE)x + H^2 - LE = 0 \ldots\ldots(6)$$

at the eight points in which these lines are cut by the hyperbola (3).

(*c*) By adding together equations (4) and (5), we get

$$\{(Bx + E)y + Cx^3 + Fx + H\}^2 = 0,$$

from which it is evident (III) that *the two supplementary curves touch each other at eight points, which lie on the hyperbola* (3).

(*d*) Let a straight line be drawn from the origin A to any point P (x, y) on the curve (4), cutting the hyperbola (3) in the points Q_1 and Q_2, and meeting the four straight lines (6) in the points R_1, R_2, R_3, R_4; then, (V),

$$\frac{PQ_1 . PQ_2}{AQ_1 . AQ_2} = \frac{(Bx + E)y + Cx^3 + Fx + H}{H},$$

$$\frac{PR_1 . PR_2 . PR_3 . PR_4}{AR_1 . AR_2 . AR_3 . AR_4} = \frac{(C^2 - BD)x^4 + \&c \ldots\ldots + (H^2 - LE)}{H^2 - LE};$$

and in virtue of these equation (4) becomes

$$H^2 . \left(\frac{PQ_1 . PQ_2}{AQ_1 . AQ_2}\right)^2 = (H^2 - LE)\frac{PR_1 . PR_2 . PR_3 . PR_4}{AR_1 . AR_2 . AR_3 . AR_4} \ldots(7).$$

If the same straight line meet the curve (5) in a real point P, we should find, in a similar manner

$$H^2 . \left(\frac{PQ_1 . PQ_2}{AQ_1 . AQ_2}\right)^2 = (LE - H^2)\frac{PR_1 . PR_2 . PR_3 . PR_4}{AR_1 . AR_2 . AR_3 . AR_4} \ldots(8).$$

Hence we see that *each of the supplementary curves* (4) *and* (5) *can be considered as the locus of a point* P, *such that*

$$\frac{PR_1 . PR_2 . PR_3 . PR_4}{AR_1 . AR_2 . AR_3 . AR_4} \text{ is to } \left(\frac{PQ_1 . PQ_2}{AQ_1 . AQ_2}\right)^2$$

in a fixed ratio; and thus, in a geometrical point of view, the curves (4) and (5) can be considered as two branches of the same curve.

IX.

If the equation to a given curve be of the form

$$y^2 - 2y . \phi x + (\psi x)^2 = 0,$$

where ϕ and ψ denote any given functions, it is required to find the supplementary curve in relation to a system of straight lines parallel to the axis of y.

By solving the equation as a quadratic, we obtain

$$y = \phi x \pm \sqrt{\{(\phi x)^2 - (\psi x)^2\}} \ldots\ldots\ldots\ldots (1),$$

from which it is evident (VI, *b*) that the equation of the required curve will be

$$y = \phi x \pm \sqrt{\{(\psi x)^2 - (\phi x)^2\}} \ldots\ldots\ldots\ldots (2).$$

(*a*) It is evident from the last two equations that the curve whose equation is

$$y = \phi x \ldots\ldots\ldots\ldots (3)$$

bisects all chords of the curves (1) and (2) which are parallel to the axis of y. Hence *the curvilinear diameter which bisects chords parallel to the axis of* y *is common to the supplementary curves* (1) *and* (2).

(*b*) By clearing the equations (1) and (2) of radicals, we obtain

$$(y - \phi x)^2 = (\phi x)^2 - (\psi x)^2 \ldots\ldots\ldots\ldots (4),$$

$$(y - \phi x)^2 = (\psi x)^2 - (\phi x)^2 \ldots\ldots\ldots\ldots (5);$$

from which it is evident (III) that *each of the supplementary curves touches the system of straight lines represented by the equation*

$$(\phi x)^2 - (\psi x)^2 = 0 \ldots\ldots\ldots\ldots (6)$$

at the points in which these lines are cut by the diametral curve (3).

(*c*) By taking the sum of equations (4) and (5) we obtain

$$(y - \phi x)^2 = 0,$$

from which we see (III) that *the supplementary curves* (4) *and* (5) *touch each other at each of the points in which they are cut by the curve* (3).

(*d*) Let a straight line be drawn from the origin A to any point P in the curve (4), meeting the curve (3) in the points Q_1, Q_2, Q_3, &c., and meeting the system of straight lines (4) in the points R_1, R_2, R_3, &c.; then if ϕx be an algebraic function of x of the nth degree, and ψx one of the mth degree, where m is not greater than n, we shall have (V)

$$\frac{PQ_1 \cdot PQ_2 \cdot PQ_3 \ldots\ldots PQ_n}{AQ_1 \cdot AQ_2 \cdot AQ_3 \ldots\ldots AQ_n} = \pm \frac{y - \phi x}{M},$$

$$\frac{PR_1 \cdot PR_2 \cdot PR_3 \ldots\ldots PR_{2n}}{AR_1 \cdot AR_2 \cdot AR_3 \ldots\ldots AR_{2n}} = \frac{(\phi x)^2 - (\psi x)^2}{T},$$

where M and T are the absolute terms of the functions ϕx and $(\phi x)^2 - (\psi x)^2$ respectively. Hence, by substituting these geometrical expressions in equation (4), it becomes

$$M^2 \left(\frac{PQ_1 \cdot PQ_2 \ldots PQ_n}{AQ_1 \cdot AQ_2 \ldots AQ_n}\right) = T \frac{PR_1 \cdot PR_2 \ldots PR_{2n}}{AR_1 \cdot AR_2 \ldots AR_{2n}} \ldots\ldots (7).$$

Similarly, if the same straight line meet the curve (5) in any point P, we shall have

$$M^2 \left(\frac{PQ_1 \cdot PQ_2 \ldots PQ_n}{AQ_1 \cdot AQ_2 \ldots AQ_n}\right) = -T \frac{PR_1 \cdot PR_2 \ldots PR_{2n}}{AR_1 \cdot AR_2 \ldots AR_{2n}} \ldots\ldots (8).$$

From the last two equations it is evident that *each of the supplementary curves can be considered as the locus of a point* P *such that*

$$\frac{PR_1 \cdot PR_2 \ldots\ldots PR_{2n}}{AR_1 \cdot AR_2 \ldots\ldots AR_{2n}} \text{ is to } \left(\frac{PQ_1 \cdot PQ_2 \ldots\ldots PQ_n}{AQ_1 \cdot AQ_2 \ldots\ldots AQ_n}\right)^2$$

in a fixed ratio; and thus we see that the two curves (4) and (5) can be considered as two branches of a geometrical locus, which is determined by a unique geometrical condition.

x.

In some cases the equation to the supplementary curve can be obtained with great facility. Thus, the equation to the *Conchoid of Nicomedes* being

$$m^2 x^2 = (p - x)^2 (x^2 + y^2) \ldots\ldots\ldots\ldots (1),$$

it is evident that the equation of the curve which is supplementary to it in relation to the axis of y will be

$$m^2 x^2 = (p - x)^2 (x^2 - y^2 \ldots\ldots\ldots\ldots (2),$$

and the supplementary curves (1) and (2) will possess properties analogous to those which have been noticed in the preceding examples.

(*a*) It is evident from the form of these equations, that the origin is a double point on each of the supplemementary curves (1) and (2). For the curve (1) the tangents at this point are represented by the equation

$$p^2 y^2 + (p^2 - m^2) x^2 = 0 \ldots\ldots\ldots\ldots (3),$$

and for the curve (2) they are represented by the equation

$$-p^2 y^2 + (p^2 - m^2) x^2 = 0 \ldots\ldots\ldots\ldots (4).$$

(*b*) When $m > p$, the tangents (3) are real and the tangents (4) are imaginary, so that the origin is a double point of the curve (1) and a conjugate point of the curve (2); but, when $m < p$, the tangents (4) are real, and the tangents (3) are

imaginary, so that the origin is a double point of the curve (2) and a conjugate point of the curve (1). Thus we see that *a double point on one of the curves is a conjugate point on the supplementary curve; and that the real and imaginary tangents, applied at that point to the two curves, form two supplementary systems of straight lines.*

(*c*) When $m = p$, each of the equations (3) and (4) becomes $y^2 = 0$; hence, in this case, the axis of x is a double tangent to each of the supplementary curves (1) and (2) at the origin. Hence we see that *when a curve has a cusp, this point will also be a cusp on the curve which is supplementary to the given one in relation to the double tangent at its cusp.*

Section III.—Of Curves which are Supplementary in relation to a given Point.

XI.

A curve of the second degree being given, to find the locus of the imaginary points in which it is cut by a system of straight lines which pass through a given point A.

When the given point A is without the curve, so that two real tangents can be drawn from it to the curve, it is evident that innumerable straight lines can be drawn through the point so that each of them shall cut the curve in two imaginary points; but when the given point is on the curve, or within it, it is plain that no straight line can be drawn through A to meet the curve in any imaginary point. Hence it will be sufficient to consider the case in which the given point A is without the given curve, since the locus cannot exist in any other case.

If the given point A be taken as the origin of rectangular co-ordinates, the equation to the given curve will be of the form

$$Ay^2 + 2Bxy + Cx^2 + 2Dy + 2Ex + F = 0.$$

Let ρ and θ denote the polar co-ordinates of the point x, y; then, by dividing the preceding equation by ρ^2, we obtain

$$A\sin^2\theta+2B\sin\theta\cos\theta+C\cos^2\theta+2(D\sin\theta+E\cos\theta)\tfrac{1}{\rho}+F(\tfrac{1}{\rho})^2=0;$$

$$\therefore\ F:\rho=-(D\sin\theta+E\cos\theta)$$

$$\pm\sqrt{\{(D\sin\theta+E\cos\theta)^2-F(A\sin^2\theta+2B\sin\theta\cos\theta+C\cos^2\theta)\}}\ldots(1)$$

is the polar equation of the given curve, and by changing the algebraic sign of the quantity under the radical sign, we shall have

$$F:\rho=-(D\sin\theta+E\cos\theta)$$

$$\pm\sqrt{\{F(A\sin^2\theta+2B\sin\theta\cos\theta+C\cos^2\theta)-(D\sin\theta+E\cos\theta)^2\}}\ldots(2)$$

which is the polar equation of the required locus.

(*a*) Since any value of θ which gives real values of ρ in equation (2) will give imaginary values of ρ in equation (1), it follows that the given curve (1) may be considered as the locus of the imaginary points in which the curve (2) is cut by any system of straight lines passing through the given point. Hence if any straight line passing through A cut either of the curves in two real points, these may also be considered as imaginary points on the other curve. From the analogy of this property to the one obtained above (VI, *a*), the curves (1) and (2) may be considered as *supplementary in relation to the given point* A. And, in general, *any two curves may be said to be supplementary in relation to a given point*, when any straight line drawn through the point meets one of the curves in p real and q imaginary points, which can also be considered as p imaginary and q real points on the other curve.

(*b*) By passing from polar to rectangular co-ordinates, and by clearing the radicals, equations (1) and (2) become

$$(Dy+Ex+F)^2=-F(Ay^2+2Bxy+Cx^2)+(Dy+Ex)^2\ldots(3),$$

$$(Dy+Ex+F)^2=F(Ay^2+2Bxy+Cx^2)-(Dy+Ex)^2\ldots(4),$$

hence we see (II, 8) that each of the curves (1) and (2) touches the two straight lines represented by the equation

$$(D^2 - AF)y^2 + 2(DE - BF)xy + (E^2 - CF)x^2 = 0 \ldots(5),$$

the equation of the chord of contact being

$$Dy + Ex + F = 0 \ldots\ldots\ldots\ldots(6),$$

which is therefore the polar of the given point A taken in relation to each of the given curves. Hence *if two conic sections be supplementary in relation to a given point, the polars of the point taken in relation to the two conic sections are coincident in direction.*

(*c*) By adding together equations (3) and (4), we obtain

$$(Dy + Ex + F)^2 = 0;$$

from which we see that the curves (3) and (4) have a double contact, the straight line (6) being the chord of contact. Hence, *two conic sections which are supplementary in relation to a given point have a double contact, the chord of contact being the polar of the given point in relation to each of the curves.*

(*d*) When the given curve is a hyperbola, having its centre at the given point, we have $D = 0$ and $E = 0$, so that equations (3) and (4) become

$$Ay^2 + 2Bxy + Cx^2 + F = 0 \ldots\ldots\ldots\ldots(7),$$

$$Ay^2 + 2Bxy + Cx^2 - F = 0 \ldots\ldots\ldots\ldots(8).$$

In this case the curves have been called conjugate hyperbolas; hence we see that *any two conjugate hyperbolas are supplementary in relation to their common centre.*

(*e*) From any point $P(x, y)$ in the curve (3) let PQ be drawn perpendicular to the straight line (6), and let PR_1 and PR_2 be perpendicular to the straight lines (5); then (V, c) we shall have

$$Dx + Ey + F = PQ \cdot \sqrt{(D^2 + E^2)},$$

$$(D^2 - AF)y^2 + 2(DE - BF)xy + (E^2 - CF)x^2 = M \cdot PR_1 \cdot PR_2,$$

where $M^2 = \{D^2 - E^2 - F(A - C)\}^2 + 4(DE - BF)^2$...(9);

and by substituting these expressions in equation (3) we get

$$(D^2 + E^2) \cdot PQ^2 = M \cdot PR_1 \cdot PR_2 \ldots\ldots\ldots\ldots (10).$$

Similarly, if perpendiculars be drawn from any point P in the curve (4) to the straight lines (5) and (6), and if the same notation be adopted, we shall have

$$(D^2 + E^2) \cdot PQ^2 = -M \cdot PR_1 \cdot PR_2 \ldots\ldots\ldots\ldots (11).$$

Thus we see that *each of the supplementary curves* (3) *and* (4) *may be considered as the locus of a point, such that if perpendiculars be drawn from it to the three straight lines* (5) *and* (6), *the product of the perpendiculars drawn to the straight lines* (5) *shall have a given ratio to the square of the third perpendicular; the algebraic sign of this ratio being different for the two curves, but its absolute magnitude being the same for both.* From this theorem it is evident (VI, *h*) that the curves (3) and (4) may be considered as branches of the same geometrical curve, although the whole curve cannot be represented by either of these equations unless we take in the imaginary values of the variables.

(*f*) We have seen (IV) that any two conic sections described in a plane have at least one real point of intersection of conjugate common secants. Now when the four points of intersection of the given curves are all imaginary, if the curves be constructed which are supplementary to the given ones in relation to a real point of intersection of conjugate common secants, since each of these curves passes through all the imaginary points of its supplementary curve, it follows that the supplementary curves will cut each other in four real points, which are the imaginary points of intersection of the two given curves. Hence when two conic sections are entirely exterior to each other, or when one of them is entirely within the other, their imaginary points of intersection may be obtained by constructing the curves which are supplementary

to the given ones in relation to a point of intersection of conjugate common secants of the two given curves.

XII.

To find the curve which is supplementary to a given curve of the fourth degree, in relation to a double point A on the given curve.

If the point A be taken as the origin of rectangular co-ordinates, the equation to the given curve will be of the form

$$\begin{aligned} &Ay^4 + By^3x + Cy^2x^2 + Dyx^3 + Ex^4 \\ &+ 2(A'y^3 + B'y^2x + C'yx^2 + D'x^3) \\ &+ A''y^2 + B''xy + C''x^2 = 0 \quad \ldots\ldots\ldots\ldots(1). \end{aligned}$$

Let r and θ be the polar co-ordinates of the point x, y; then, the preceding equation becomes

$$A_1r^4 + 2B_1r^3 + C_1r^2 = 0 \quad \ldots\ldots\ldots\ldots(2),$$

where, for the sake of brevity, we assume

$$\left.\begin{aligned} A_1 &= A\sin^4\theta + B\sin^3\theta\cos\theta + \&c. \\ B_1 &= A'\sin^3\theta + B'\sin^2\theta\cos\theta + \&c. \\ C_1 &= A''\sin^2\theta + B''\sin\theta\cos\theta + C''\cos^2\theta \end{aligned}\right\} \ldots\ldots(3).$$

Now, by rejecting the common factor r^2, and solving equation (2) as a quadratic, we get

$$A_1r = -B_1 \pm \sqrt{(B_1^2 - A_1C_1)} \quad \ldots\ldots\ldots\ldots(4),$$

which may be considered as the polar equation of the given curve; and by changing the algebraic signs of the quantities under the radical sign, we obtain

$$A_1r = -B_1 \pm \sqrt{(A_1C_1 - B_1^2)} \quad \ldots\ldots\ldots\ldots(5),$$

which is the polar equation of the required curve. It is evident from the values of A_1, B_1, C_1 given above, that the

curve (5) is of the eighth degree, the origin being a multiple point of the sixth order.

(*a*) It is evident from the forms of the equations (4) and (5), that the curve whose equation is

$$A_1 r + B_1 = 0 \ldots\ldots\ldots\ldots (6)$$

bisects every chord of either curve which passes through the origin A. Hence *the locus of the points of bisection of all chords of the curves* (4) *and* (5) *which pass through the common multiple point* A, *is a curve of the fourth degree having* A *for a triple point.*

(*b*) By clearing the equations (4) and (5) of radicals, we obtain

$$(A_1 r + B_1)^2 = B_1^2 - A_1 C_1 \ldots\ldots\ldots\ldots (7),$$

$$(A_1 r + B_1)^2 = A_1 C_1 - B_1^2 \ldots\ldots\ldots\ldots (8);$$

from which it is evident (III) that *each of the supplementary curves touches the system of straight lines represented by the equation*

$$B_1^2 - A_1 C_1 = 0 \ldots\ldots\ldots\ldots (9)$$

at the points in which these lines are cut by the curve (6). Hence, also, the supplementary curves touch each other at the points in question.

(*c*) If a straight line be drawn from the origin A to any point P on either of the supplementary curves, cutting the curve (6) in the points Q_1, Q_2, Q_3, Q_4; and if PR_1, PR_2, PR_3, &c. be the perpendiculars drawn from P to the system of straight lines (9), we should find as in No. XI. that

$$PR_1 . PR_2 \ldots\ldots PR_6 \text{ is to } \left(\frac{PQ_1 . PQ_2 . PQ_3 . PQ_4}{AQ_1 . AQ_2 . AQ_3 . AQ_4}\right)^3$$

in a fixed ratio; and therefore the two supplementary curves (4) and (5) may be considered as branches of a geometrical locus, all the points of which are determined by a unique geometrical condition.

XIII.

The results which have been obtained in the last two numbers can be extended to a certain class of algebraic curves of every degree. Thus, if a curve of the nth degree have a multiple point of the order $n-2$, and if this point be taken as the origin of rectangular co-ordinates, the polar equation of the curve will be of the form

$$A_1 r^n + 2 B_1 r^{n-1} + C_1 r^{n-2} = 0,$$

where A_1, B_1, C_1, are algebraic functions of $\sin\theta$ and $\cos\theta$ of the degrees n, $n-1$, and $n-2$ respectively. Rejecting the common factor r^{n-2}, and solving this equation as a quadratic, we obtain

$$A_1 r = -B_1 \pm \sqrt{(B_1^2 - A_1 C_1)} \ldots\ldots\ldots\ldots (1);$$

and by changing the algebraic signs of the quantities under the radical sign we get

$$A_1 r = -B_1 \pm \sqrt{(A_1 C_1 - B_1^2)} \ldots\ldots\ldots\ldots (2),$$

which is the polar equation of the curve supplementary to the given one in relation to the multiple point which we have taken as the origin of co-ordinates. Since these equations are of the same form as those obtained in the last two numbers, the same reasoning will lead to results in every respect similar to those which have been there developed.

XIV.

The reader will not fail to perceive that the theory which I have endeavoured to explain can be extended to surfaces with the utmost facility. In the case of supplementary surfaces, the general problem to be solved is as follows:—

Any surface being given, to find the locus of the imaginary points in which it is cut by a system of straight lines, drawn so as to succeed one another according to any given law.

For instance, if the given surface be one of the second degree, and if the system of straight lines be drawn parallel to a given line, we should find, as in No. VI., that the supplementary surface is also one of the second degree touching the given surface along the plane curve in which it is cut by the diametral plane which bisects chords parallel to the given line. And as the preliminary propositions in Section I. can readily be extended to surfaces, the two supplementary surfaces will be found to possess properties exactly analogous to those developed in the notes to No. VI. But having extended this paper rather beyond the prescribed limits, I must conclude by merely pointing out to the reader a fertile and interesting field of inquiry, which, as far as I know, has not been hitherto investigated.

IX.—*On the influence of Sun-heated Land in producing Ascending Atmospheric Currents.*

By Mr. Thos. Hopkins.

[*Read April 5th*, 1853.]

The Hadleyan theory of the trade winds is founded upon the supposed influence of the rarefaction of the atmosphere of the torrid zone by the direct action of solar heat. The Rev. T. Milner, in his recent work called the *Gallery of Nature*, gives this explanation of that theory; he says—"As the sun is always vertical at some place within the tropics, the average temperature in that region is much higher than in latitudes to the north and south, and the incumbent air is thereby rarefied and expanded. The consequence is, that, in obedience to hydrostatic laws, masses of air are *continually buoyed up from the surface, or swelled round the torrid zone in the form of a protuberant belt, the upper strata flowing over and running off in streams north and south towards the poles*, where, having been cooled and condensed, they descend and flow over the surface towards the equator, *pouring in a perpetual current of air to supply the place of that forced up by the heat of the tropics*."—(p. 440.) And such is, in substance, the theory of winds which is found in all modern books that treat on Meteorology. Yet this theory is not only unsupported by facts, but directly at variance with many of them,—nearly the whole of those known having a bearing on the subject tending to show, not the truth, but the falsity of the theory. That the surface of

the earth being in parts raised to a high temperature will to some extent communicate that temperature to the air resting upon it, making it rise, and allowing cool air to supply its place, is to a small extent true; but that this kind of heating of the air produces the important effects ascribed to it, is not shown by reference to any known facts. It is therefore to be viewed as only a plausible conjecture which has been advanced and adopted in the absence of sufficient real knowledge of the subject.

I have, in former papers, shown that the influence of such heating of the land as has been referred to, on the atmosphere, is feeble and incapable of producing the strong winds, including those called the trade winds, that blow in many parts of the world; but it is desirable that we should go more fully into the subject, and trace more particularly the real effects of heating the surface of land by the sun, on the air resting on the land. It must be observed that it is not merely the geographical position of the tropics that is supposed to cause the air to rise, but the high temperature of the surface of the land, and of the air resting upon it, as a consequence of that position. It therefore follows that where the surface is the most heated by direct solar influence, the effect spoken of should be experienced in the highest degree; and the large areas on the earth's surface which are the most heated should have the air over them the most swelled and buoyed up, allowing cold air to flow towards them below in the most palpable and decided manner. Now there are a number of such places respecting which we have tolerably full information, and all that is necessary to be done, is, that we should collect that information, and ascertain the nature of the evidence which it furnishes relating to the truth or the falsity of the theory under consideration.

It is well known that it is not upon the equatorial belt that the most highly sun-heated land is found, or where such lands exist to the greatest extent, though most of them are within

or near to the tropics; some, however, extending considerably beyond that limit. From the equator up to the latitude of 30°, or, in certain parts, to 40° north, much sun-heated land is found in the summer; and an inquiry into the state of the air over these lands at that time, and its various movements about them, will enable us to judge of the influence of direct solar heating of the surface of the land, on the atmosphere which rests upon it. The deserts of Bokhara and Tartary, for instance, extend far north, and they are raised to a very high temperature in the summer; we may therefore begin by adverting to the influence of direct solar heat on their atmospheres. They may be considered as extending from the Sea of Aral, in 45° north, towards the south. Accounts pretty generally agree in representing the summer temperature here as reaching to 100° of Fahrenheit. Burnes, in his *Travels*, says—"After having passed the Oxus, the country was entirely destitute of water, but the wind blew steadily *from the north*, (the hot country in the summer,) from which quarter it blows constantly,—nor do I believe that it would be possible to traverse this tract in the summer, if it ceased to blow." Yet nearly south of this part there exist extensive ranges of mountains covered with snow during the whole of the summer, which of course have a very low temperature. Here then, if there were truth in the theory under consideration, we might reasonably expect to find air ascending from the heated surface, and other air flowing in from colder districts. But not a breath of air appears to pass from the parts that are covered with snow to the hot land of the desert. On the contrary, the wind blows steadily from the part which is highly heated at the time; that is, the wind blows from the hot desert towards the cold mountains, giving no countenance to the theory.

It may be imagined, however, that the atmosphere, though it does not ascend here, rises from surface-heated land somewhere further south; but this we shall find on inquiry is not

the fact; for in the Persian deserts to the south, as well as across the arid country of Beloochistan, the wind continues to blow from the heated north during the whole summer, producing the great dryness that is found there. At Bagdad and Bushire the thermometer sometimes stands as high as 135°, yet no fact can be traced in the locality to countenance the idea that any atmospheric current ascends from the part.

The great desert of Arabia, a considerable portion of which is west of Persia, but a large part south of it, and much of it lying within the northern tropic, presents the same general features as the more northern and eastern deserts just spoken of. It is not however to be supposed that the winds, as they pass over these extensive and rugged countries, are never to any extent disturbed in their courses by local influences. Mountains and hills, there is no doubt, do and will more or less affect them, and cause local deviations from their general course. But the powerful cause that produces the great general wind, seems to have sufficient force to overcome these partial influences, and to determine the motion of the aggregate mass of the atmosphere.

The land in the broad expanse of the desert of Arabia is probably raised to as high a temperature by the direct action of the solar rays as any extensive portion of the surface of the earth; and if the mass of air resting on it could be raised and made to overflow by mere surface heating, it would most undoubtedly here ascend energetically and flow away in the upper regions, leaving other air to come in below from any contiguous part, but particularly from the comparatively cool adjoining Arabian Sea. What, however, are the facts of the case? Why, the general wind continues to blow over the heated surface until it reaches and then passes over the Arabian Sea; that is, it moves from a hot surface to a cool one. This large mass of air, coming from the heated lands already described, makes its way over the hot deserts and

round the bases of the snowy mountains of Hindoo-Koosh and Afghanistan, passing over the comparatively cool waters of the Persian Gulf and the Arabian Sea, and finally rushes over the northern plains of Hindoostan to the Himalaya Mountains, where it really does ascend. These plains, however, are not then highly heated by the direct action of the sun upon them, as the surfaces of the deserts were over which the wind had passed, the plains of Hindoostan being at this season screened from the solar rays by a thick canopy of clouds.

There appears to be a partial exception to this general state of Hindoostan, over the mouth of the Indus and Cutch, where the Monsoon generally sets in at the end of June, but during the months of July, August, and September the winds are observed to cause drought.* Now these dry winds evidently come from Beloochistan and Arabia, and not having crossed a sufficient extent of sea to become charged with vapour, they pass towards the great area of condensation near the mountains as dry winds. The state of this locality therefore proves the real nature of the causes that are in operation to produce the effects that are experienced.

The whole of the facts show that the cause of the continued flow of air over the extensive surfaces of the dry, heated deserts that have been named, is to be found in the large amount of condensation of vapour that is taking place against the lofty Himalaya Mountains, which vapour is known to have been brought from the Indian Ocean; and its condensation is shown to be able to produce a comparative vacuum, and to create an ascending current powerful enough to draw air from the remote distances that have been named. The moving mass constitutes a general north wind in the deserts of Bokhara and Persia, and a north-west wind over Arabia, and it is converted into a west wind in its passage across the Arabian Sea; these various directions being

* See Mrs. Postans' book *On Cutch*, p. 259.

evidently determined by the large amount of condensation of vapour that is taking place at the time against the Himalaya Mountains. We have then evidence, in the whole range of country we have traversed, that dry, solar heating of air does not produce ascending atmospheric currents and their consequent horizontal winds. We also see what does produce them. We perceive that they are produced by condensation of vapour; the evidence may therefore be considered conclusive as far as respects the parts that have been passed under review.

But the great desert of Northern Africa is the part generally pointed out by those who say that the heat of dry land produces important ascending aërial currents. Respecting this desert, "Dr. Oudney, in the course of his long journey from Tripoli to Lake Tchad, estimated the elevation of the southern Sahara at 1,637 feet. The French engineer, Fournel, has by careful barometric measurement based on corresponding observations, made it probable that a part of the northern desert is below the level of the sea. Between Biscara and Sidi Ocba the ground is only 243 feet above the level of the sea."* And Milner says that "from the west coast of Africa, and between Morocco on the north and the Senegal river on the south, this wilderness extends easterly to the Red Sea. It embraces a space of more than 46° of longitude and 15° of latitude, or a length of 3,000 miles by a breadth of 1,000. A large extent of the Sahara is a dead level; but low sand hills, wadys or valleys, and projecting rocks, are frequent."—(p. 226.) It is stated by the same writer to be "like an immense furnace, warming all the regions on the Mediterranean Sea, in the south of Europe and the west of Asia." It will however be found on inquiry, that the meteorological facts relating to this desert present no evidence to sustain such an opinion. There is no reason to suppose that the heated air of this desert rises and flows over

* See Humboldt's *Aspects of Nature*, p. 115.

these countries and warms them. A moderate flow of air *from the north* appears to pass over Algiers and Tripoli to the desert in an irregular and fluctuating way; but it passes over the whole desert, leaving it nearly destitute of water, and probably in some manner, not open to observation at present, feeds the north-east trade wind of the Atlantic. But the only continuous winds that have a decided character in the whole of this extensive area, are the north wind that blows up the Valley of the Nile, and the Harmattan, which issues from the desert and terminates in the Atlantic.

That wind which blows up the Nile becomes strong in the month of June, a time when the desert is much heated by the sun, and it is known to continue blowing up the river as far as Abyssinia. Speaking of it, a compiler says—"The mists which are exhaled from the Mediterranean by heat, and which frequently obscure the Egyptian sky, are carried by the north winds over the flat country, without interruption, until they are arrested by the mountains of central Africa."* But this part of Africa is, as compared with the desert, a cold country, being much elevated; the wind therefore blows along a border of the heated desert to feed a distant part. As stated by Lizars, it may be distinctly traced as coming from the Mediterranean and the countries beyond it, and, in blowing up the Valley of the Nile, it passes near the imaginary vacuum over the desert, and proceeds to a part where we find, as we did near the Himalaya Mountains, that at the time rain is falling very freely, as is proved by the subsequent rise of the Nile. Now if the hot Sahara heated the air that rested upon it, and made it swell and ascend to the higher regions, allowing cooler air to flow in below to supply its place, in the way that has been asserted, this current of air which now goes to Abyssinia would most undoubtedly be drawn towards the interior of the desert, to feed the imaginary ascending current. But as it is not so drawn, it is to be presumed that no such current exists over the desert.

* Lizars, p. 262.

The accounts which we have of other winds that occasionally blow on the same side of the Sahara represent them as coming from *the west*, that is, from the desert, and towards the Valley of the Nile. This is so decidedly the prevalent direction of these winds, as to cause them to carry the loose sand of the desert towards the river. It is confidently said that this sand has long been covering the land on the west bank of the river, and converting it into desert. Now if air generally ascended from the desert, such a wind would not exist; it is therefore also evidence in favour of the non-existence of an ascending aërial current within the desert.

Another wind is sometimes encountered in this part of the world, which is thus described in a popular Geographical work: "Egypt is liable in spring, for a period of fifty days, to the terrible wind of the desert called *the Simoom*, which from its intense heat and dryness threatens, when long continued, the extinction of animal life. It seldom, however, continues above three days." This wind is probably caused by a local ascending aërial current, as it raises large masses of the sand of the desert to a considerable height. It is generally accompanied by a thick cloud, which intercepts the light of the sun to such an extent as to bring on darkness like that of the night; there must, therefore, notwithstanding the dryness of the air below, be a considerable amount of condensation of vapour taking place above, in order to produce the cloud. One writer, describing this wind, says—"We knew not where we were, and could not distinguish anything at the distance of a foot. The sand wrapped us in darkness, like a fog, and the sky and the earth seemed confounded and blended together."—*Caillé.** The precise operating cause

* It is recorded that "in August, 1819, a fierce Simoom blew at Bagdad, while the temperature was very high, and a heavy rain falling, an unprecedented event, the whole region was converted into a vast hot steam bath."—Milner, p. 495. And Mr. Richardson, the recent African traveller, describes the sudden descent of a large body of water in what had just before been a dry valley of the Sahara. These are instances of the Simoom evidently producing an atmospheric current which ascended high enough to condense the vapour that was in it, but this does not appear to occur often.

of this extraordinary wind we have no means of determining, the requisite meteorological information not having been furnished, but it is stated to come *from* the desert, and to continue but a short time; it cannot therefore be taken as evidence of the existence of such an ascending current within the desert, as is under consideration. Such evidence as it furnishes is indeed in favour of the non-existence of such a current, or of the means of producing one. If sufficient vapour existed in the part, it would be carried up by the Simoom, and would produce continued rain, as it does in rainy localities.

The *Harmattan* is a wind that blows on the surface of the desert, *from* the interior towards the Atlantic Ocean, passing for some distance over the sea. It is irregular in its occurrence, although more frequent in our winter than at other times. It blows with considerable force, and often lasts for a number of days. The following is a description of this wind by Milner. He says—"The Harmattan, a periodical wind from the desert, differs remarkably from the Simoom. It blows from the interior of the great Sahara, from the north-east over Senegambia and Guinea, to that part of the coast of Africa that is between Cape Verde, in fifteen degrees of north latitude, and Cape Lopez, in one degree of south latitude, a coast line of upwards of 2,000 miles. It occurs during December, January, and February, generally three or four times in the season. It comes on indiscriminately at any hour of the day, at any time of the tide, or at any period of the moon, continuing sometimes only a day or two, at other times five or six days, and it has been known to last for upwards of a fortnight. It blows out to sea for ten or twelve leagues. Extreme dryness is another property of the Harmattan: no dew falls during its continuance, nor is there the least appearance of moisture in the atmosphere." This account of the Harmattan shows that it blows over *the surface* of the earth, and *from* the desert,

which is the reverse of what would take place if heated air over the desert were ascending to the higher regions, and overflowing to adjoining countries.

Teneriffe, one of the Canary Islands, is to the north of the locality where the Harmattan blows, and Humboldt says that when he was on the Peak of that island, a west wind blew with violence, though the island below was under the ordinary influence of the north-east trade wind. But this shows a state of things just the reverse of what would be found if heated air ascended from the desert. Under such circumstances there would be a west wind blowing below from the cool sea and towards the heated land, and the air which rose from the desert would *overflow*, and if towards the sea, in the upper regions. Thus all the facts of the case that have been passed under our view, are at variance with the common theory of ascending currents from sun-heated land. The water of the sea in this part of the Atlantic Ocean, it may be observed, comes from the north, it being the place of termination of the great gulf stream that flows from Newfoundland by Ireland; but no continued wind can be traced, even in the summer, blowing from this cool sea to the heated desert. Captain Fitzroy, when writing of this part, says—"At St. Jago, the wind being always from the north or east from December to June, a ship can moor as close to the weather shore as may be convenient; but from July to October no vessel should deem the bay of Porto Praya secure, or anchor near the shore, because *southerly* gales sometimes blow with great strength."* Thus we see that all winds are found to blow in this part except westerly, which would be the principal, if not the only one, if air ascended from the desert and overflowed in the upper regions.

There is another wind which must not be passed unnoticed, as it may possibly be thought to countenance the ideas here combatted. It blows more or less throughout the year from

* Fitzroy, p. 51.

the west, that is, from the Gulf of Guinea towards the main land of Africa. But it passes over the equatorial parts *towards a mountainous region where heavy rains are falling*, and not towards the heated desert. Thus, among all the winds that are found to blow in or about this desert country of northern Africa, the surface of which is in the summer greatly heated, not one blows in a direction and with a constancy that accords with the assertion that heated air ascends within it; whilst two winds evidently blow from it—one, the Harmattan, on the western side, and the other on the eastern side, carrying sand towards the Nile.

The imperfect accounts which we have of the interior of this great desert of stones and sand, with a few oases, state that although the ground is greatly heated by the sun during the day, yet at night its temperature sinks to a low degree, as compared with that of the day; *the mass* of the atmosphere is therefore probably not greatly heated. From many facts, it appears that the solar heat which is accumulated near the ground in the day, is rapidly dissipated by radiation through a clear sky at night; and the mean temperature of the air at a moderate height, if taken at each of the twenty-four hours, would probably be found not high. In the parts near to the Mediterranean where scarcely any rain falls, heavy dew moistens the earth; from which moisture the deceptive mirage so often described is probably produced. But further in the interior no dew is formed even by the great cold of the nights; the air must therefore be very dry, and the sky is said to be generally without clouds. Humboldt says that "the high temperature of the air of the desert which makes the day's march so oppressive, renders the cold of the nights (of which Denham complained so often in the African, and Sir A. Burnes in the Asiatic desert) so much more striking. Melloni ascribes this cold, produced doubtless by radiation from the ground, less to the great purity and serenity of the sky than to the profound calm, the nightly absence of all movement in the

atmosphere."* This calm is however itself a consequence of the absence of all condensation of vapour.

A wind is occasionally felt on the south-west coast of Italy which is said to come from Africa—the following account of it is from Milner. "It is (he says) a hot south-east wind, prevailing in the Mediterranean, in Italy and in Sicily, but felt most violently in the country around Naples and at Palermo. It sometimes commences faintly about the summer solstice, but blows occasionally with great force in the month of July. There can be little doubt (he continues) that this hot south-east wind sweeps across the Mediterranean from Africa." But if it does, it evidently comes as a lower wind sweeping the surface of the sea, from which it no doubt takes up the moisture for which it is remarkable: as proof, therefore, that the Desert heats air and causes it to ascend, as heated air is assumed to rise within the tropics, it entirely fails.

If air from the Mediterranean Sea or the Atlantic Ocean flowed freely towards the interior of this African desert, and there became heated and ascended to a considerable height, it would by that ascent expand and cool; and having taken up vapour from the surface of the sea, as it must have done, would produce first cloud and in due time rain. It is because there *is not* a sufficient swelling and rising over the desert that the country is so dry. There is no land sufficiently elevated to force up the air to such a height as shall bring on successive condensation and create ascending currents, strong enough to cause air to flow as a wind to the desert. Air rushes up the Valley of the Nile to the mountains of Abyssinia, and from the Gulf of Guinea to other mountains, because the vapour that it carries is condensed against their sides; but air does not flow from the adjoining seas into the Sahara, because there is no sufficient condensation of vapour there. If the Abyssinian mountains extended across

* *Aspects of Nature*, vol. i., p. 117.

the desert to the Atlas range, there is little reason to doubt that the air which now goes to Abyssinia might in part flow towards such mountains; or winds similar to those which now blow from the Gulf of Guinea, might then rush from the Canary Islands, across the now dry deserts to the same elevated land. There would then be not only ascending currents in the air, but rain to water the earth, and if the imaginary mountains were sufficiently lofty, large rivers might flow through the present parched deserts to the sea, as they do now from the Abyssinian and Himalaya mountains.

But it is only proper that the following passage, which I have seen since the foregoing was written, in Humboldt's *Aspects of Nature*, should be given. This eminent philosopher says—"It is a remarkable phenomenon, *well known among sailors*, that in the vicinity of the African coast, between the Canaries and the Cape de Verde Islands, and particularly between Cape Bojador and the mouth of the Senegal, a west wind often takes the place of the general east or trade wind of the tropics. It is the wide expanse of the Desert of Sahara which causes this westerly wind. The air over the heated sandy plains becomes rarefied and ascends, the air from the sea rushing in to supply the void so formed, and thus there *sometimes* arises a west wind adverse to ships bound to the American coast, which are made in this manner to feel the vicinity of the heat-radiating desert, without even seeing the continent to which it belongs. The changes of land and sea breezes which blow alternately at certain hours of the day or night, on all coasts, are due to the same cause."—(vol. i., p. 61.) From this passage it is probable that the eminent writer was so imbued with the idea that air must rise from sun-heated land, as to induce him to refer facts which he found stated to that cause, without making any further inquiry on the subject. But if heated land really produced the effect, should we have only such meagre evidence of it as that given? The general

wind of the part is admitted to be the eastern trade wind, and it is stated that there only "sometimes arises a west wind," and it is characterised as "a remarkable phenomenon." It is well known that winds blow to some extent, on all coasts, from the sea to the land, because there are generally some elevations on the land, not far from the sea, up which air ascends when cloud is formed and rain falls. But such winds are more feeble and less constant on this than on other coasts; indeed, they are so much exceptions to the general state of the part as to be unnoticed by nearly all the writers that I have happened to meet with. If, however, this immense desert acted on the atmosphere in the way assumed, the west wind from the cool sea would be nearly always blowing, and would be very strong during the summer days. This coast is but little known, but on some maps hills or mountains are marked, and there may be such sufficiently high to produce occasional rains. This is most likely the fact, as the mouths of a number of short rivers are marked on the maps, such as the River Cyprian, in latitude 22°, and the River Del Ouro, near the tropics. As, however, Humboldt states that the cause of the west wind is the same as that which produces land and sea breezes on coasts, and as there are no accounts of daily sea breezes along these coasts—though they are known to exist southward at Sierra Leone,—even the statement of this eminent philosopher proves little more than that, in the great extent and variety of his inquiries, he has sometimes adopted the general opinions which he found in books, without carefully examining the evidence on which they rest.

To enable us to reason upon the real causes that produce ascending currents, let us suppose that a broad belt of the present equatorial land was all low and flat like the Valley of the Amazon, and that mountains similar to those existing at present in America and Africa in certain parts about the equator extended across the Atlantic Ocean, on the outside

of the northern tropic, as the Himalayas do, there being no other mountains near; and then endeavour to consider how the atmosphere within the tropics would be affected by such a state of things. From the evidence already adduced, it is reasonable to infer that evaporation would take place from the tropical seas, as at present, and the air over them would be pretty fully saturated with vapour. But as there would be no elevated land near those seas excepting the imagined mountains to the north, the slight disturbances which are always occuring in the atmosphere would force some of this vapour up the imagined mountains, and produce such ascending currents as would draw all the air and vapour from the tropical seas towards themselves. Winds would then blow from the tropical seas towards the north, leaving the imagined low belt of tropical land in Africa and America a dry desert. The temperature of the air over this land might possibly reach 120° or 140°, but there is no reason to believe that such air would rise and flow over in the upper regions towards either pole, seeing that there would be no condensation going on in it. But while the temperature of the air over the sea near to the mountains would probably rise only to about 80°, and even that temperature be limited to the part near the surface, a temperature very high for the elevation would be carried up the mountains, where the expansion of the air would nevertheless condense an abundance of vapour and produce copious rains and strong winds.

Now we have facts similar to these in the existing state of things near the tropics, with the exceptions of the particular localities of the mountains and deserts. The imagined deserts would be only such as now exist in Arabia and Africa, and the mountains would be similar to the present Himalaya range. It would not be more surprising that vapour should then pass from the tropical Atlantic Ocean to be condensed against mountains to the north, than it is that it now passes

from the Southern Indian Ocean to the Himalayas. At present, in the summer monsoon of the Indian Ocean, vapour passes from Madagascar to the Himalaya Mountains—from north to south, through sixty degrees of latitude, and it might equally well pass over the tropical Atlantic to northern mountains. This would prove, by the evidence of new facts, that direct solar heating within the tropics did not cause the air to swell and ascend—and flow over in the higher regions towards the poles. The tropical lands would then be more heated by the direct solar rays than they are now, but air would no more rise from them than it does at present from the deserts of Arabia and Africa.

Without further adverting to local modifications of winds, it is conceived that we are authorised to conclude that sun-heated surfaces of land do not produce ascending atmospheric currents which overflow in the higher regions to distant colder parts.

LIST OF BOOKS

PRESENTED TO THIS SOCIETY FROM NOVEMBER 16TH, 1852, TO MAY, 1853.

Donors.	Titles of Books.
GEOLOGICAL SOCIETY, LONDON.	Quarterly Journal of the Geological Sociey, Vol. VIII., Part 4, and Vol. IX.
COUNCIL OF THE PHILOSOPHICAL AND LITERARY SOCIETY, LEEDS.	Leeds Philosophical and Literary Society, Annual Reports for 1850-51 and 1851-52.
COUNCIL OF THE PHILOSOPHICAL SOCIETY, GLASGOW.	Proceedings of the Philosophical Society of Glasgow, Vol. III., No. 4. 1851-52.
F. GRACE CALVERT, Esq.	Reports on the Examination of the Supply of Water to Preston.
" "	Reports on the bad quality of Chemical Products and Drugs.
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Literary and Philosophical Society, Kingston-upon-Hull.	Twenty-ninth Annual Report of the Literary and Philosophical Society of Kingston-upon-Hull.
Societè de Physique et d'Histoire Naturelle de Genève.	Memoire de la Societè de Physique et d'Histoire Naturelle de Genève, Tome XIII., Part 1st, 1852.
A. J. Bernays, Esq., F.C.S.	Household Chemistry; or, Rudiments of the Science applied to every-day Life. By Albert J. Bernays, Esq., F.C.S.
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" "	Proceedings of the Royal Irish Academy, Vol. V., Part 2. 1852.
Historic Society of Lancashire and Cheshire.	Proceedings and Papers—Session 4th—1851-52—Historic Society of Lancashire and Cheshire.
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